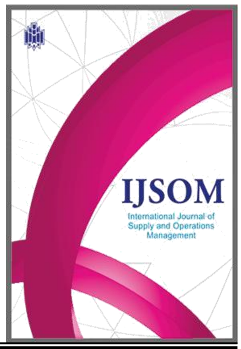
International Journal of Supply and Operations Management

IJSOM

November 2021, Volume 8, Issue 4, pp. 478-490
ISSN-Print: 2383-1359
ISSN-Online: 2383-2525
www.ijsom.com



Manufacturer-retailer Inventory Model for Deteriorating Items with Fixed Lifetime and Two-level Trade Credit Having Credit-linked Price-dependent Demand

Hetal R. Patel[a,*]

[a,*] *Ganpat University- U. V. Patel College of Engineering, Ganpat Vidyanagar, Gujarat, India*

Abstract

Supply chain containing two-level i.e. single-manufacturer and single-retailer is considered assuming time varying deterioration rate. The units deteriorate in the warehouse and two-level credit is offered. Demand function is the increasing function of retailer's credit offered to the consumers. Under the agreed contract, manufacturers offer trade credit in the form of delay payment to the retailers such that profit will be shared jointly. Modelling of mathematical computation is done with a view to maximize total joint profit in the supply chain. Next, numerical examples are discussed, followed by sensitivity analysis to validate the outcomes of solution procedure.

Keywords: Deterioration; Profit sharing; Trade credit; Price sensitive demand.

1. Introduction

Industrial engineering and management science put great emphasize on productivity which is an important dimension of inventory management. In reality, all the stakeholders of supply chain such as manufacturers/suppliers/retailers works on their consumption with minimum lose (Rai, 2020). In the business transactions, cash-on-delivery has become less preferable among the set of choices by retailers. Therefore, suppliers offer trade credits to attract more retailers so as they buy more in supply chain. Trade credit also helps suppliers to control demand, and promote items to boost sales (Mahata, Mahata and De, 2020). Usually, it is wide spread that up-stream suppliers offer a fixed credit period to down-stream retailers in traditional SC inventory models. However, customers are offered a credit period by retailers to promote the market competition (Mahata, Mahata and De, 2018). The trade credit concept is first formulated by Goyal (1985). Moreover, Shah, Soni and Jaggi (2010) provided a detail review of inventory model having trade credit in consideration. The trade credit among the entities of supply chain helps to settle their account (Rai, 2020).

Simply, Giri and Sharma (2015) defined up-stream as "when manufacturer or retailer receives a full trade credit from its suppliers". A little attention on defaulter risk has been paid by scholars to the practice of down-stream retailers' partial credit to credit risk customers. Down-stream is referred as "when retailers offer a partial trade credit to its credit-risk customers" (Giri and Sharma, 2015). Studies such as Huang (2003, 2006, 2007, 2008), Teng and Goyal (2007), Liao (2008) have focused on trade credit into inventory modelling. However, in practice, the items which are deteriorating in nature that loses utility after certain time period, creates a problem to all the entities.
Mahata, Mahata and De (2019) states that products such as "vegetables, fruits, volatile liquids, blood banks, fashion merchandises and high-tech products deteriorate continuously due to several reasons such as evaporation, spoilage, obsolescence among others" (p. 2). In this context, notable studies have been evidenced in the literature using trade credit for deteriorating items. For example, Mahata (2012) formulated production model with deterioration using supplier's offering full credit to retailers and customers receive partial credit from retailers. Extending the work by Mahata (2012) with an offering appropriate solution procedure, Chen, Teng and Skouri (2014) developed an EPQ model for deteriorating items providing different approach for earned interest and payable interest.

* Corresponding author email address: hrp07@ganpatuniversity.ac.in
DOI: 10.22034/IJSOM.2021.4.7

Credit policies have been further considered in computation of inventory model by Chung et al. (2014), Feng, Moon and Ryu (2014), Jiang et al. (2014) etc. Moreover, Shah (2015) studied manufacture-retailer relationships under "two-level-trade-credit with price-sensitive-demand. In recent times, Heyderi and Norouzinasab (2016) considered two-echelon manufacturing supply chain with credit policy. Mahata and De (2016) offered a solution to the two-level trade credit for ameliorating items with an assumption of constant amelioration rate. Mixed type trade credit was also used by Shaikh (2017) using selling price-dependent demand.

In fact to avoid non-payment risks, many down-stream entities get partial trade credit from manufacturers/suppliers. Tiwari, Ahmed and Sarkar (2019) demonstrated the application of making ordering policy sustainable using carbon credits with trade credit. Admittedly, Pramanik and Maiti (2019) presented solution with "two-level partial trade credit" considering the demand which is "inflation-induced". The computation of EOQ for items that deteriorates with "time-varying-rate" was presented by Mahata, Mahata and De (2020). In most of researches on deteriorating inventory modeling under trade credit financing assume constant deterioration rate, constant demand rate and in some instances stock-dependent and time-dependent demand rate (Soni, 2013). However in reality, demand always changes with price, time and delayed payment period. Additionally, credit period on sales is marginally dependent on the unrealized potential market demand. To gain constitution and generalized outcomes, we assume price and credit sensitive demand along with time-dependent-deterioration rate.

This paper aims to enhance total profit of integrated supply chain model with deterioration for single manufacturer and single retailer, with two-level trade credit assumed. The rest of the study is structured as follow: notations and assumptions are presented, followed by mathematical model formulation in next section. The computation of optimal solution is established numerical examples showing theoretical results and insights for practice followed by sensitivity analysis. The model helps to get insights on formulating profit sharing strategy.

2. Problem Description and Formulation

In this paper, "supplier-manufacturer-retailer" model is considered for deteriorating items which obsolesces with passage of time. The manufacture receives a full credit from its supplier which is further offered partially to their retailers with profit sharing contract. Retailer settles the account with manufacturer by acquiring loan from bank and by paying loan at the end of cycle. The purpose of this paper is to maximize manufacturer's net profit along with retailers' net profit.

The study considers the manufacturer-linked profit and retailer-linked profit and therefore to compute profits, separate notations are used to structure the problem which is listed as under:

Parameters relevant to manufacturer

K_m	Manufacturer setup cost per unit
c_{h_m}	Carrying cost of the Inventory per unit time
c_{p_m}	Manufacturer's unit purchasing cost of a product
P	Production rate
T_m	Delayed period in which production starts
M	Fixed-credit-period provided to the retailer by manufacturer (in year)
I_{lm}	Loss of interest occurred because of offering a credit period
δ	Fraction of Manufacturer's profit share from the retailer for the credit period $M; 0<\delta<1$
μ_m	Manufacturer's earning per unit time

Parameters relevant to retailers

K_r	Per order cost of retailer

c_{h_r}	Per unit retailer's inventory carrying cost per unit time
c_{p_r}	Per unit retailer's purchase cost
p	Per unit selling price
I_b	Bank Rate of interest on the loan borrowed
I_e	Per unit Interest for a given credit time
ε	Fraction of consumers permitted by the retailer to service credit period $N; 0 \le \varepsilon \le 1$
m	Maximum life of the commodity
$\theta(t)$	Deterioration rate of products in warehouse where $\theta(t) = \frac{1}{1+m-t}, 0 \le t \le T \le m$
$D(p,N)$	Retailer's demand rate where $D(p,N) = a - bp + e^{cN}$; N and p are decision parameters. Further, scale demand is present when $a > 0$, price elasticity markup is present when $b > 0$ and trade-credit markup is present when $c > 0$.
T	Product replenishment time (T is a decision variable)
μ_r	Retailer's earning per unit time

All the parameters of inventory which are used in the formulation of this inventory problem are interlinked as follows: $I_b > I_\theta$, $N \le M$, $p > c_{p_r} > c_{p_m}$, $T_m = \gamma T$, $0 < \gamma < 1$. Further, the assumptions used in proposing the aforementioned problem are used as under:

1. Instantaneous replenishment and infinite planning horizon is assumed.
2. The deteriorate unit cannot be changed or repaired during the cycle time.
3. A supply chain is subject to single deteriorating product, single manufacturer and single retailer.
4. Credit period reduces inventory holding cost so there is positive impact on demand. So retailer's rate of demand is $D(p,N) = a - bp + e^{cN}$. D and $D(p,N)$ are interchangeable.
5. To avoid shortages, a constant production rate P is considered in such a way that $P > D$.
6. During $T \ge M$, the manufacturer provides trade credit to the retailer with the agreement that manufacture will receive fraction of profit incurred during the credit period M. The account settled at $T = M$, to settle the accounts with manufacturer, retailer takes bank loan at the rate I_b and pays loan when cycle ends. Further, at times when $T \le M$, retailer has enough sum to pay for the purchases so there is no need for retailer to borrow any loan. So retailer does not pay any interest on the stock when $T \le M$.
7. As manufacturer provides credit period, he incurs interest loss at the rate I_{lm} per unit per unit time.

3. Mathematical model

In this paper, the models presented include costs such as primary cost (ordering cost, purchasing cost), holding costs, and profit per unit time (for retailer and manufacturer). The joint profit of the supply chain is also included.

3.1. Inventory Model of Retailer

The retailer's inventory reduces due to time dependent deterioration defined as $\theta(t)=\frac{1}{1+m-t}, 0\le t\le T\le m$ in special case where θ′ (t) ≥ 0 and θ (m) = 1 and price sensitive credit linked demand in the warehouse. The instantaneous state of the inventory at any point of time $t\in[0,T]$ is given by

$$\frac{dI_r(t)}{dt}=-D-\left(\frac{1}{1+m-t}\right)I_r(t), 0\le t\le T \tag{1}$$

with $I_r(t)=0$

By solving Eq. (1) yield:

$$I_r(t)=(1+m-t)D\ln\left(\frac{1+m-t}{1+m-T}\right) \tag{2}$$

The retailer's inventory level starts with $Q=I_r(0)=(1+m)D\ln\left(\frac{1+m}{1+m-T}\right)$

Hence, the primary costs incurred by retailer are as under:

$PC_r=\frac{c_{p_r}}{T}Q$ (Purchase cost) and $OC_r=\frac{K_r}{T}$ (Ordering cost)

$$HC_r=\frac{c_{h_r}}{T}\int_0^T I_r(t)\,dt \qquad \text{(Holding cost)}$$

$$=\frac{c_{h_r}D}{2T}\left[\ln\left(\frac{1+m}{1+m-T}\right)(1+m)^2+\frac{T^2}{2}-T(1+m)\right]$$

Using M (manufacturer offering credit) and N (retailer offering credit) for given T (cycle time), following potential cases can be discuss.

Case 1: $N\le M\le T$

In this case, revenue accumulates by the retailer is as $SR_r=\frac{p}{T}\int_0^T D\,dt=pD$

Deduction from the revenue to calculate net profit can be discussed in following way.

As per agreement, the retailer has to pay $\delta\%$ of profit to the manufacturer. So, the part of shared profit is $FP_1=\frac{\delta\left(p-c_{p_r}\right)DM}{T}$ and left amount can be used to cover the expenses incurred for managing the account. For the time period of M where trade credit is allowed, retailer borrows money at the rate I_b from the bank per unit and repays at T when cycle gets over. Considering this, the bank's net interest to be paid is calculated as

$$ICB_r=\frac{I_b}{T}(T-M)\left[c_{p_r}T-pM+\delta\left(p-c_{p_r}\right)M\right]$$

Per unit time retailer's earning in the form of interest for the cycle time (T) is

$$IE_{r1} = \frac{pI_e}{T}\left[\int_0^M Dt\,dt + \int_0^{T-M} Dt\,dt\right]$$
$$= \frac{pI_e D}{2T}\left[M^2 + \left(T-M\right)^2\right]$$

Because of providing trade credit to the consumer, opportunity loss incurred by the retailer as,

$$OL_{r1} = \frac{\varepsilon pI_e}{T}\int_0^N Dt\,dt$$
$$= \frac{\varepsilon pI_e DN^2}{2T}$$

Using this inputs, net profit per unit time (μ_{r1}) for retailer is computed as

$$\mu_{r1}\left(N, p, T\right) = SR_r - PC_r - FP_1 - OC_r - HC_r - ICB_r - OL_{r1} + IE_{r1}$$

Case 2: $N \le T \le M$

In this case, sharing of profit is, $FP_2 = \delta\left(p - c_{p_r}\right)D$ and the interest earned by the retailer for T (per unit cycle time) is calculated as $IE_{r2} = \frac{pI_e}{T}\left[\int_0^T Dt\,dt + Q\left(M-T\right)\right]$.

Because of permitting consumer trade credits, opportunity loss incurred by the retailer is:

$$OL_{r1} = \frac{\varepsilon pI_e}{T}\int_0^N Dt\,dt$$
$$= \frac{\varepsilon pI_e DN^2}{2T}$$

Here, as T (cycle time) $\le M$ (the time period where trade credit is allowed), retailer has enough amounts so there is no need to borrow any loan for retailer ($I_b = 0$) . Therefore, retailer's net profit, μ_{r2} per unit time is

$$\mu_{r2}\left(N, p, T\right) = SR_r - PC_r - FP_2 - OC_r - HC_r - OL_{r2} + IE_{r2}$$

Case 3: $T \le N \le M$

In this case, sharing of profit is, $FP_3 = \delta\left(p - c_{p_r}\right)D$ and during cycle time T , interest earned by the retailer per unit time is $IE_{r3} = \frac{pI_e}{T}\left[\int_0^T Dt\,dt + Q\left(M-T\right)\right]$. Therefore, the retailer's opportunity loss is determined as

$$OL_{r3} = \frac{\varepsilon p I_e}{T}\left[\int_0^N Dt\,dt + Q\left(N-T\right)\right]$$
$$= \frac{\varepsilon p I_e}{T}\left[\frac{DN^2}{2} + \left(1+m\right)D\ln\left(\frac{1+m}{1+m-T}\right)\left(N-T\right)\right]$$

Here, the respective cycle ends before the completion of credit period offered. Therefore, no interest charges are borne on retailer (I_b = 0). Also, there is no interest loss as manufacturer is sharing the fraction of the profits. Therefore, per unit retailer's net profit (μ_{r3}) is derived as

$$\mu_{r3}\left(N, p, T\right) = SR_r - PC_r - FP_3 - OC_r - HC_r - OL_{r3} + IE_{r3}$$

3.2. Manufacturer's Inventory Model

Differential equation is used to calculate inventory rate of change at the warehouse of manufacturer at any point of time $t \in \left[0, T\right]$ as

$$\frac{dI_m\left(t\right)}{dt} = P - \frac{1}{1+m-t} I_m\left(t\right), T_m \le t \le T \tag{3}$$

with $I_m\left(T\right) = 0$.

On solving the equation, one has

$$I_m\left(t\right) = P\ln\left(\frac{1+m-Tm}{1+m-t}\right)\left(1+m-t\right), 0 < t < T \tag{4}$$

The primary costs of the manufacturer are as under:

Per unit holding cost over time period is

$$HC_m = \frac{c_{h_m}}{T}\int_{T_m}^{T} I_m\left(t\right)dt$$
$$= -\frac{c_{h_m}P}{4T}\left[\ln\left(\frac{1+m-T_m}{1+m-T}\right)\left(2T^2 - 4mT - 4T + 2\left(1+m\right)^2\right) + T^2 - 2mT - T_m{}^2 + 2mT_m - 2T + 2T_m\right]$$

The per unit time setup cost is $OC_m = \dfrac{K_m}{T}$

Due to credit period (M) offered to the retailer, per unit time loss of interest is calculated as,

$$OL_m = \frac{c_{p_m} P I_{lm}\left(T - T_m\right)M}{T}$$

During the credit period, manufacturer gains δ percentage of share of retailer's profit as per the agreement. So, manufacturers' share in profit for given time is obtained as

$$FP_m = \begin{cases} FP_{m1} = \dfrac{\delta MD}{T}\left(p - c_{p_r}\right), M \le T \\ FP_{m2} = \quad \delta D\left(p - c_{p_r}\right), M > T \end{cases}$$

Hence, net profit of the manufacturer per unit time is

$$\mu_{m1}(T) = \left(c_{p_r} - c_{p_m}\right)D - OC_m - HC_m - OL_m + FP_{m1}, M \le T$$
$$\mu_{m2}(T) = \left(c_{p_r} - c_{p_m}\right)D - OC_m - HC_m - OL_m + FP_{m2}, M > T$$

Joint profit of the supply chain
The joint profit of the integrated supply chain is

$$\prod(N, p, T) = \begin{cases} \mu_1(N, p, T) = \mu_{r1}(N, p, T) + \mu_{m1}(T), N \le M \le T \\ \mu_2(N, p, T) = \mu_{r2}(N, p, T) + \mu_{m2}(T), N \le T \le M \\ \mu_3(N, p, T) = \mu_{r3}(N, p, T) + \mu_{m2}(T), T \le N \le M \end{cases}$$

Optimization problem of the supply chain is

$$\begin{aligned} &\text{Maximize} \quad \prod = \mu_m + \mu_r \\ &\text{subject to} \quad N, p, T \ge 0 \end{aligned}$$

Considering any values of N *and* p, equations $\mu_1(M / p, \mathrm{N}) = \mu_2(M / p, N)$ and $\mu_2(N / p, N) = \mu_3(N / p, N)$ are received. To further arrive at the optimal solution $\left(N^*, p^*, T^*\right)$, the appropriate algorithm is presented as under:

Step 1: All parameters of inventory with its numerical values should be fixed.

Step 2: Let $\dfrac{\partial \mu_i}{\partial N} = 0, \dfrac{\partial \mu_i}{\partial p} = 0$ and $\dfrac{\partial \mu_i}{\partial T} = 0, i = 1, 2, 3$ and solve this using Maple 17.0 simultaneously for N, p and T. Also determine the best optimal value offering the joint profit.

Step 3: Lastly, use a graphical presentation to check the sufficient condition.

4. Numerical Example

Numerical example is presented to illustrate theoretical results using following data. Consider $a = 600, b = 3.5, c = 2.2, \delta = 0.4, \varepsilon = 0.75, \gamma = 0.01, K_r = 50, K_m = 200, c_h = 10, c_{h_m} = 2, c_p = 50, c_{p_m} = 10, P = 1000, I_\varepsilon = 0.09, I_b = 0.15, I_{im} = 0.18, M = 0.3, m = 2$ in appropriate units.

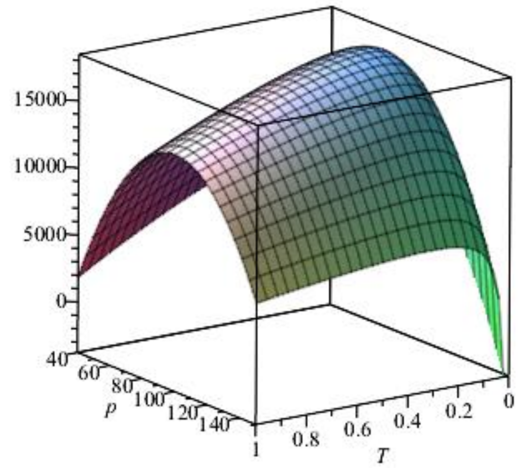


Figure 1. Concavity of total profit of the supply chain when $N = 0.0218$ for $N \le T \le M$

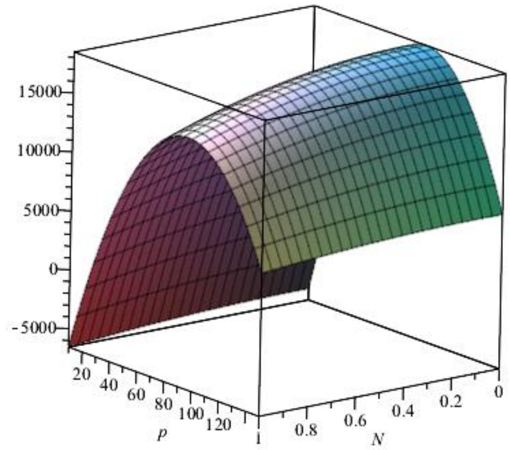


Figure 2. Concavity of total profit of the supply chain when $T = 0.2020$ for $N \le T \le M$

Using maple 17 software, optimal profit is $\mu_2 = \$18463.30$ by offering credit period $N = 0.0218$ years to the consumer for a cycle time $T = 0.2020$ years at retail price $p = \$92.15$ per unit. For obtained values:

$$\begin{vmatrix} \frac{\partial^2 \mu_2}{\partial T^2} & \frac{\partial^2 \mu_2}{\partial T \partial p} & \frac{\partial^2 \mu_2}{\partial T \partial N} \\ \frac{\partial^2 \mu_2}{\partial T \partial p} & \frac{\partial^2 \mu_2}{\partial p^2} & \frac{\partial^2 \mu_2}{\partial p \partial N} \\ \frac{\partial^2 \mu_2}{\partial T \partial N} & \frac{\partial^2 \mu_2}{\partial p \partial N} & \frac{\partial^2 \mu_2}{\partial N^2} \end{vmatrix} = -3.634866929 \times 10^9 < 0$$

which shows the concavity of the profit for $N \le T \le M$. Figure 1 and 2 is presented concavity of total profit of the supply chain when N and T are given. While, when p is given, the concavity of the total profit of the supply chain is shown in figure 3.

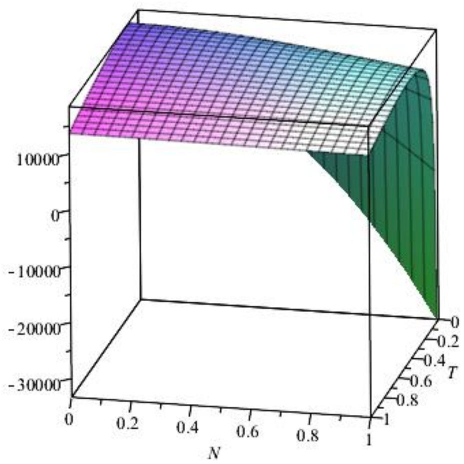


Figure 3. Concavity of total profit of the supply chain

when $p = 92.15$ for $N \le T \le M$

5. Sensitivity Analysis

This section used the data of above mentioned example for performing sensitivity analysis. We changed one parameter at a time by -30%, -20%, -10%, +10%, +20% and +30% with other parameters constant and study its effect on decision variables like profit, trade credit (*N*) given to the consumer by the retailer, retail price, p and cycle time, *T*. On the basis of computational results displayed in Table 1 the following managerial insights are received.

Table 1: Sensitivity analysis of parameters

Parameter	Value	N^*	T^*	p^*	TP^*	Case
a	420	0.0374	0.2441	66.78	6765.44	2
	480	0.0306	0.2282	75.23	10278.7	2
	540	0.0256	0.2146	83.70	14322	2
	600	0.0218	0.2028	92.18	18894.4	2
	660	0.0188	0.1926	100.68	23995.5	2
	720	0.0165	0.1835	109.18	29624.8	2
	780	0.0145	0.1753	117.69	35782	2
b	2.45	0.0212	0.1936	128.91	30062.5	2
	2.8	0.0215	0.1972	113.61	25404.9	2
	3.15	0.0217	0.2002	101.70	21786.1	2
	3.5	0.0218	0.2028	92.18	18894.4	2
	3.85	0.0219	0.2052	84.40	16531.3	2
	4.2	0.0220	0.2073	77.91	14564.8	2
	4.55	0.0220	0.2093	72.42	12903.2	2
c	1.54	0.0149	0.2028	92.18	18893.4	2
	1.76	0.0171	0.2028	92.18	18893.7	2
	1.98	0.0194	0.2028	92.18	18894	2
	2.2	0.0218	0.2028	92.18	18894.4	2
	2.42	0.0242	0.2029	92.19	18894.8	2
	2.64	0.0268	0.2029	92.19	18895.3	2
	2.86	0.0294	0.2030	92.19	18895.8	2
δ	0.28	0.0218	0.2028	92.18	18894.4	2
	0.32	0.0218	0.2028	92.18	18894.4	2
	0.36	0.0218	0.2028	92.18	18894.4	2
	0.4	0.0218	0.2028	92.18	18894.4	2
	0.44	0.0218	0.2028	92.18	18894.4	2
	0.48	0.0218	0.2028	92.18	18894.4	2
	0.52	0.0218	0.2028	92.18	18894.4	2
ε	0.525	0.0318	0.2029	92.19	18895.3	2
	0.6	0.0276	0.2029	92.19	18894.9	2
	0.675	0.0243	0.2029	92.18	18894.6	2
	0.75	0.0218	0.2028	92.18	18894.4	2
	0.825	0.0197	0.2028	92.18	18894.2	2
	0.9	0.0180	0.2028	92.18	18894.1	2
	0.975	0.0166	0.2028	92.18	18893.9	2
γ	0.035	0.0217	0.2024	92.18	18855	2
	0.04	0.0218	0.2026	92.18	18868.1	2
	0.045	0.0218	0.2027	92.18	18881.3	2
	0.05	0.0218	0.2028	92.18	18894.4	2
	0.055	0.0218	0.2030	92.18	18907.5	2
	0.06	0.0218	0.2031	92.19	18920.6	2
	0.065	0.0218	0.2033	92.19	18933.7	2
	35	0.0211	0.1968	92.14	18969.4	2

Parameter	Value	N^*	T^*	p^*	TP^*	Case
K_r	40	0.0213	0.1989	92.15	18944.2	2
	45	0.0216	0.2009	92.17	18919.2	2
	50	0.0218	0.2028	92.18	18894.4	2
	55	0.0220	0.2048	92.20	18869.9	2
	60	0.0222	0.2067	92.21	18845.6	2
	65	0.0224	0.2087	92.23	18821.5	2
K_m	140	0.0190	0.1775	92.00	19209.8	2
	160	0.0200	0.1864	92.06	19099.9	2
	180	0.0209	0.1948	92.12	18995	2
	200	0.0218	0.2028	92.18	18894.4	2
	220	0.0226	0.2106	92.24	18797.6	2
	240	0.0235	0.2180	92.30	18704.3	2
	260	0.0242	0.2251	92.35	18614	2
c_{h_r}	7	0.0226	0.2102	92.08	18982.8	2
	8	0.0223	0.2077	92.11	18952.9	2
	9	0.0221	0.2052	92.15	18923.5	2
	10	0.0218	0.2028	92.18	18894.4	2
	11	0.0215	0.2006	92.22	18865.7	2
	12	0.0213	0.1984	92.25	18837.3	2
	13	0.0210	0.1962	92.28	18809.2	2
c_{h_m}	1.4	0.0223	0.2072	92.22	18948.7	2
	1.6	0.0221	0.2057	92.20	18930.5	2
	1.8	0.0219	0.2043	92.19	18912.4	2
	2	0.0218	0.2028	92.18	18894.4	2
	2.2	0.0216	0.2015	92.17	18876.5	2
	2.4	0.0215	0.2001	92.16	18858.8	2
	2.6	0.0213	0.1988	92.15	18841.2	2
c_{p_r}	35	0.0233	0.2163	92.00	19688.7	2
	40	0.0228	0.2115	92.07	19422.7	2
	45	0.0223	0.2070	92.13	19158	2
	50	0.0218	0.2028	92.18	18894.4	2
	55	0.0213	0.1989	92.24	18631.9	2
	60	0.0209	0.1952	92.29	18370.3	2
	65	0.0205	0.1917	92.35	18109.8	2
c_{p_m}	7	0.0220	0.2016	90.69	19737.4	2
	8	0.0219	0.2020	91.19	19454.7	2
	9	0.0219	0.2024	91.69	19173.7	2
	10	0.0218	0.2028	92.18	18894.4	2
	11	0.0217	0.2033	92.68	18616.9	2
	12	0.0216	0.2037	93.18	18341.1	2
	13	0.0216	0.2041	93.67	18067	2
P	700	0.0223	0.2072	92.22	19589.9	2
	800	0.0221	0.2057	92.20	19358	2
	900	0.0219	0.2043	92.19	19126.1	2
	1000	0.0218	0.2028	92.18	18894.4	2
	1100	0.0216	0.2015	92.17	18662.8	2
	1200	0.0215	0.2001	92.16	18431.3	2
	1300	0.0213	0.1988	92.15	18200	2
I_e	0.063	0.0327	0.2092	92.26	18792.3	2
	0.072	0.0281	0.2070	92.23	18826	2
	0.081	0.0246	0.2049	92.21	18860	2
	0.09	0.0218	0.2028	92.18	18894.4	2
	0.099	0.0196	0.2009	92.16	18929	2

Parameter	Value	N^*	T^*	p^*	TP^*	Case
	0.108	0.0177	0.1990	92.14	18963.9	2
	0.117	0.0162	0.1971	92.11	18999.1	2
I_b	0.105	0.0218	0.2028	92.18	18894.4	2
	0.12	0.0218	0.2028	92.18	18894.4	2
	0.135	0.0218	0.2028	92.18	18894.4	2
	0.15	0.0218	0.2028	92.18	18894.4	2
	0.165	0.0218	0.2028	92.18	18894.4	2
	0.18	0.0218	0.2028	92.18	18894.4	2
	0.195	0.0218	0.2028	92.18	18894.4	2
I_{lm}	0.126	0.0218	0.2028	92.18	19535.6	2
	0.144	0.0218	0.2028	92.18	19321.9	2
	0.162	0.0218	0.2028	92.18	19108.1	2
	0.18	0.0218	0.2028	92.18	18894.4	2
	0.198	0.0218	0.2028	92.18	18680.6	2
	0.216	0.0218	0.2028	92.18	18466.9	2
	0.234	0.0218	0.2028	92.18	18253.1	2
M	0.175	0.0234	0.2180	92.42	19391.5	1
	0.2	0.0237	0.2210	92.39	19215.1	1
	0.225	0.0217	0.2027	92.20	19048.4	2
	0.25	0.0218	0.2028	92.18	18894.4	2
	0.275	0.0219	0.2030	92.17	18740.4	2
	0.3	0.0219	0.2032	92.16	18586.5	2
	0.325	0.0220	0.2033	92.14	18432.5	2
m	1.4	0.0206	0.1921	92.32	18768.1	2
	1.6	0.0210	0.1961	92.27	18816.1	2
	1.8	0.0214	0.1996	92.23	18857.8	2
	2	0.0218	0.2028	92.18	18894.4	2
	2.2	0.0221	0.2058	92.15	18926.8	2
	2.4	0.0224	0.2085	92.11	18955.6	2
	2.6	0.0227	0.2109	92.08	18981.5	2

Analysis reveals that trade credit (N) offered to the consumer by the retailer reduces with respect to demand parameter (ε), inventory holding cost (a) of both retailer and manufacturer, purchase cost of manufacturer, production rate and interest earned. Additionally, retailer's purchase cost decreases with the credit period of SC. It shows that consumers will be attracted if they have to pay less. However, N increases with respect to the demand parameters b and c, cost of manufacturer's set-up, ordering cost of retailer, manufacturer's cost of purchase, credit period offered to the retailer by manufacturer and maximum life of the product. Further, N remains constant by increasing values of parameters γ, δ, I_{lm} and I_b. Trade credit changes significantly by changing values of demand parameter a and c. Other parameters are less sensitive to the trade credit period provided by retailer to the customer.

Table 1 shows that cycle time of SC increases with increment in demand parameter b and c, γ, set-up cost of manufacturer, ordering cost of retailer, manufacturer's purchase cost, credit period given to the retailer by manufacturer and maximum life of product. Demand parameter a, holding cost of both manufacturer and retailer, retailers purchase cost, production rate and the interest earned reduces cycle time of SC. Cycle time varies significantly with changes in a, K_m, c_{h_r}, c_{p_r} and m. T Changes slightly with respect to $b, c, K_r, c_{h_m}, c_{p_m}, P$ and I_e. However, the cycle time of the supply chain does not change with changes in ε, interest rate on borrowings, profit sharing fraction, and interest loss incurred due to credit period.

With increase in demand parameter b, production rate, interest earned, inventory holding cost of manufacturer, retailer's credit period given by the manufacturer and maximum life of product, decreases the selling price. The selling price increases with increases in purchase cost of retailer and manufacturer, retailer's cost of order and manufacturers' set-up cost, inventory holding cost of the retailer and demand parameter a and c. Other inventory parameters have standard impact on selling price. Demand parameter a and b effect significantly on selling price. The demand parameter a and c, interest earned, product maximum life and γ increases supply chain's joint profit. Profit sharing fraction and interest rate on the loan does not effect on supply chain's total profit. Other parameter decreases joint profit of the supply chain. Demand parameters a and b, manufacturer's set-up cost, purchase cost of both retailer and manufacturer, production rate, loss of interest due to credit period and credit period offered by manufacturer to the retailer have significant effect on supply chains' total profit. Decision maker are warranted on said considerations while making decisions. Above shown analysis shows that most of all optimal values are received in the scenario $N \leq T \leq M$.

6. Conclusion and Future scope

The present study considers single-manufacturer and single-retailer with "two-level-trade credit financing" for supply chain. It is assumed that trade credit policy is adopted by both suppliers and manufacturer to rise demand with optimal ordering. Deterioration rate is time-dependent function. The market demand depends on credit period offered by the retailer to the consumer and retail price. During the credit cycle, profit is shared between the players of the supply chain. Numerically, it is proved that two-level-trade credit profit sharing strategy is beneficial to increase profit. Simply in practice, decrease in payment made by supplier/retailer will benefit downstream entities motivating more order for retailers. The existing inventory model can be extended by including preservation technology investment strategy. The model can be further modified considering single manufacturer and multiple buyers.

References

Chen, S. C., Teng, J. T., and Skouri, K., (2014). Economic production quantity models for deteriorating items with up-stream full trade credit and down-stream partial trade credit, *International Journal of Production Economics*, Vol. 155, pp. 302-309.

Chung, K. J., Cárdenas-Barrón, L. E., and Ting, P. S., (2014). An inventory model with non-instantaneous receipt and exponentially deteriorating items for an integrated three layer supply chain system under two levels of trade credit, *International Journal of Production Economics,* Vol. 155, pp. 310–317.

Feng, X., Moon, I., and Ryu, K., (2014). Revenue-sharing contracts in an N-stage supply chain with reliability considerations, *International Journal of Production Economics,* Vol. 147, pp. 20–29.

Goyal, S. K., (1985). Economic order quantity under conditions of permissible delay in payments, *Journal of the operational research society*, Vol. 36(4), pp. 335-338.

Heydari, J., and Norouzinasab, Y., (2016). Coordination of pricing, ordering, and lead time decisions in a manufacturing supply chain, *Journal of Industrial and Systems Engineering*, Vol. 9, pp. 1-16.

Huang, Y. F., (2003). Optimal retailer's ordering policies in the EOQ model under trade credit financing, *Journal of the Operational Research Society,* Vol. 54, pp. 1011–1015

Huang, Y. F., (2006). An inventory model under two levels of trade credit and limited storage space derived without derivatives, *Applied Mathematical Modelling,* Vol. 30, pp. 418–436.

Huang, Y. F., (2007). Optimal retailer's replenishment decisions in the EPQ model under two levels of trade credit policy", *European Journal of Operational Research,* Vol. 176, pp. 1577–1591.

Huang, Y. F., (2008). An EOQ model under retailer partial trade credit policy in supply chain, *International Journal of Production Economics*, Vol. 112, pp. 655–664.

Jiang, W., Ouyang, L. Y., Cárdenas-Barrón, L. E., and Goyal, S. K., (2014). Optimal credit period and lot size for deteriorating items with expiration dates under two-level trade credit financing, *European Journal of Operational Research,* Vol. 237, pp. 898–908.

Liao, J. J., (2008). An EOQ model with noninstantaneous receipt and exponentially deteriorating items under two-level trade credit, *International Journal of Production Economics,* Vol. 113, pp. 852–861.

Mahata, G. C., (2012). An EPQ-based inventory model for exponentially deteriorating items under retailer partial trade credit policy in supply chain", *Expert systems with Applications*, Vol. 39(3), pp. 3537-3550.

Mahata, P., Mahata, G. C., and De, S. K., (2018). Optimal replenishment and credit policy in supply chain inventory model under two levels of trade credit with time-and credit-sensitive demand involving default risk, *Journal of Industrial Engineering International*, Vol. 14(1), pp. 31-42.

Mahata, P., Mahata, G. C. and De, S.. (2020). An economic order quantity model under two-level partial trade credit for time varying deteriorating items." *International Journal of Systems Science: Operations & Logistics,* Vol. 7(1), pp. 1-17.

Pramanik, Prasenjit, and Manas Kumar Maiti. (2019). An inventory model for deteriorating items with inflation induced variable demand under two level partial trade credit: A hybrid ABC-GA approach." *Engineering Applications of Artificial Intelligence,* Vol. 85, pp. 194-207.

Rai, V., (2020). Trade Credit Policy Between Supplier–Manufacturer–Retailer for Ameliorating/Deteriorating Items, Journal *of the Operations Research Society of China*, Vol. 8(1), pp. 79-103.

Shah, N. H., (2015). Manufacturer-retailer inventory model for deteriorating items with price-sensitive credit-linked demand under two-level trade credit financing and profit sharing contract, *Cogent Engineering*, Vol. 2(1), pp. 1012989.

Shah, N. H., Soni, H., and Jaggi, C. K., (2010). Inventory models and trade credit: Review, *Control & Cybernetics*, Vol. 39, pp. 867–884.

Shaikh, A. A., (2017). An inventory model for deteriorating item with frequency of advertisement and selling price dependent demand under mixed type trade credit policy, *International Journal of Logistics Systems and Management*, Vol. 28(3), pp. 375-395.

Soni, H. N., (2013). Optimal replenishment policies for non-instantaneous deteriorating items with price and stock sensitive demand under permissible delay in payment, *International Journal of Production Economics*, Vol. 146(1) pp. 259-268.

Teng, J. T., and Goyal, S. K., (2007). Optimal ordering policies for a retailer in a supply chain with up-stream and down-stream trade credits, *Journal of the Operational Research Society,* Vol. 58, pp. 1252–1255.

Tiwari, S., Ahmed, W. and Sarkar, B., (2019). Sustainable ordering policies for non-instantaneous deteriorating items under carbon emission and multi-trade-credit-policies, *Journal of Cleaner Production*, Vol. 240, pp. 118-183.