EFFECTS OF INFLATION AND DELAY IN PAYMENTS ON FUZZY INVENTORY SYSTEM FOR PERISHABLE ITEMS WITH LEARNING EFFECTS

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ABSTRACT
In the trading market, trade credit financing is now a very useful and effective promotional tool for sellers or contractors to boost efficiency through motivating sales and an exclusive prospect for the traders to lessen demand improbability. In this scenario, a credit financing model is proposed for perishable items with the effect of learning and inflation under fuzzy environment. Demand rate, purchasing price and selling price are assumed to be in fuzzy nature. Finally, minimization of the total fuzzy inventory cost with respect to cycle length is performed. The numerical example explains the applicability of the present model. The sensitivity of the model is analyzed with the changes in the values of different parameters associated with the model and robustness is checked. The future scope is also presented in the end.

KEYWORDS: Learning effects, EOQ, Trade-credit financing policy, Perishable items, Deterioration, Inflation, Fuzzy environment.

MSC: 90B05

RESUMEN
En el mercadeo , financiar los créditos de negocio es ahora una muy útil y efectiva herramienta , para la promoción de los vendedores o contratistas, para créditos para boostear la eficiencia a través de motivar las ventas y un prospecto exclusivo para los negociadores, para disminuir la improbabilidad de demanda. En este escenario, un modelo financiero de crédito es propuesto para ítems deteriorables con el efecto de aprender sobre el financiamiento, bajo un ambiente de variables fuzzy. La tasa de demanda, precios de las distribuciones son considerados de naturaleza. Finalmente, se desarrolla la mimización del costo de inventario, respecto al inventario de costo fuzzy respecto al largo de los ciclos. El ejemplo numérico explica la aplicabilidad del presente modelo. La sensibilidad respecto a los cambios de valores de diferentes parámetros asociados al modelo se chequea la robustez . El objetivo futuro es también presentado al final.

PALABRAS CLAVE: efecto de aprendizaje, EOQ, crédito de negociado, política de financiación, ítems deteriorables, Deterioro, Inflación, ambiente.

1. INTRODUCTION

Ghare and Schrader (1963) extended the fundamental EOQ model by assuming negative exponential function with respect to time as rate for deteriorating items. This model laid foundations for the follow-up study for the deteriorating products in the inventory control management. Shah and Chaudhary (2015) formulated an integrated model with three players for deteriorating items under fixed lifetime scenario. They assumed that the demand rate is quadratically decreasing and credit period dependent. An optimal pricing and ordering policy for deteriorating items with price and stock dependent demand with partial backlogging was derived by Khurana and Chaudhary (2016). Optimal transfer, ordering and payment policies for joint supplier-buyer inventory model with price sensitive trapezoidal demand and net credit was studied by Shah et al. (2017). Review of literature and survey of developed inventory models under different situations was presented by Singh and Singh (2018). Aliyu and Sani (2018) formulated a mathematical model for deteriorating inventory with generalized exponential decreasing demand. Kumar and Rajput (2015) developed a fuzzy inventory model for deteriorating items where demand is time dependent. Shortages are fully backlogged in this model. A two-warehouse inventory model with preservation technology investment and partial backlogging was derived by Singh and Rathore (2016). Mohan (2017) suggested a model for deteriorating products having variable carrying cost. In the discussed model, quadratic demand is taken, and salvage value is also calculated. Khan et. al. (2020) proposed a profit

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maximization inventory model for perishable products where demand of product is dependent on selling price and carrying cost is linearly time varying. Buzacott (1975) developed the first EOQ model taking inflationary effects into account. In this model, uniform inflation was assumed for all the associated costs and an expression for the EOQ was derived by minimizing the annual cost. Moon and Lee (2000) also studied the effect of inflation and time value of money of economic order quantity model. Misra (1979) gave a note on optimal inventory management under inflation and developed a discount cost model in which effects of both inflation and time value of money were assumed. Jaggi et al. (2013) presented the optimal inventory replenishment policy for deteriorating items under the inflationary conditions. The demand rate was assumed to be a function of inflation and optimal solution for the proposed model was derived. Jayaswal et al. (2019) formulated an EOQ model having imperfect quality and perishable goods. In this model, trade-credit financing and concept of learning has also been discussed. Goyal (1985) pioneered in developing the inventory model when a supplier offers a credit period in settling the account, so that no interest will be charged on the outstanding amount if the account is settled within the allowable delay period. Mandal and Phaujdar (1989) have studied Goyal's model by including interest earned from the sales revenue on the stock remaining beyond the credit period.
The learning phenomenon was introduced by Wright (1936), who recommended the learning curve as power function. Another model by considering learning effect was developed by Agarwal et al. (2017) for non-instantaneous deterioration rate. A deteriorating inventory model by Kumar and Kumar (2016) discussed the effect of learning with the inventory dependent demand rate. In this scenario, it has analyzed the impact of trade credit, inflation and leaning effect on total fuzzy cost under fuzzy environment and got positive results.

2. ASSUMPTIONS AND NOTATIONS

2.1 Assumptions

The present mathematical model for perishable products having the following assumptions:

1. No replenishment of perishable items during cycle length.
2. Shortages and lead-time are not permitted.
3. Inflation rate is constant during cycle length.
4. Unit purchasing cost is less than the unit selling price, both are imprecise in nature.
5. Demand rate is a function of time and imprecise in nature when time is zero.
6. Credit financing policy is allowed from the side of seller to his customer.
7. Holding cost is time dependent.
8. Carrying cost and set-up cost are influenced by the learning effect.

2.2 Notations

$D(t)=D_0e^{-\alpha t}$	Demand rate which is the function of time
D_0	Demand rate when time is zero
$\tilde{D}_0$	Fuzzy demand rate when time is zero
$O(t)=O_ce^{rt}$	Ordering cost due to inflation when time is t
$O_c=c_1+\frac{c_2}{n^{\chi}}$,	Set-up cost which is followed the learning effect
c_1, c_2	Fixed set up cost
$h(t)=h_ct$	Holding cost
$h_c=h_1+\frac{h_2}{n^{\chi}}$,	Unit holding cost which is followed the learning effect
h_1, h_2	Fixed unit holding cost
n	Number of shipments
χ	Learning factor
$S(t)=S_ce^{rt}$	Purchasing price due to inflation per unit when time is t

S_c	Purchasing price per unit when time is zero
$\tilde{S}_c$	Fuzzy purchasing price per unit when time is zero
$P(t) = P_c e^{rt}$	Purchasing price per unit when time is t
P_c	Unit selling price per unit when time is zero
$\tilde{P}_c$	Fuzzy unit selling price per unit when time is zero
ξ	Preservation cost per unit when time is zero
θ	Decaying rate per unit time
Q	Order quantity
M	Credit period
I_c	Interest charged
I_e	Interest gained
T	Cycle length
$\Psi_1(T)$	The whole cost for the case $M \le T$
$\Psi_2(T)$	The whole cost for the case $T \le M$
$\tilde{\Psi}_1(T)$	The fuzzy whole cost for the case $M \le T$
$\tilde{\Psi}_2(T)$	The fuzzy whole cost for the case $T \le M$
$\tilde{T}_1$	Fuzzy cycle length for the case $M \le T$
$\tilde{T}_2$	Fuzzy cycle length for the case $T \le M$

3. MATHEMATICAL FORMULATION

It is considered that $l(t)$ is an inventory level at time t. Initially, the stock level is Q at $t = 0$. The inventory level decreases due to demand rate and decaying nature both till it becomes zero at time $t = T$. The inventory level depicts by the following differential equation with respect to time.

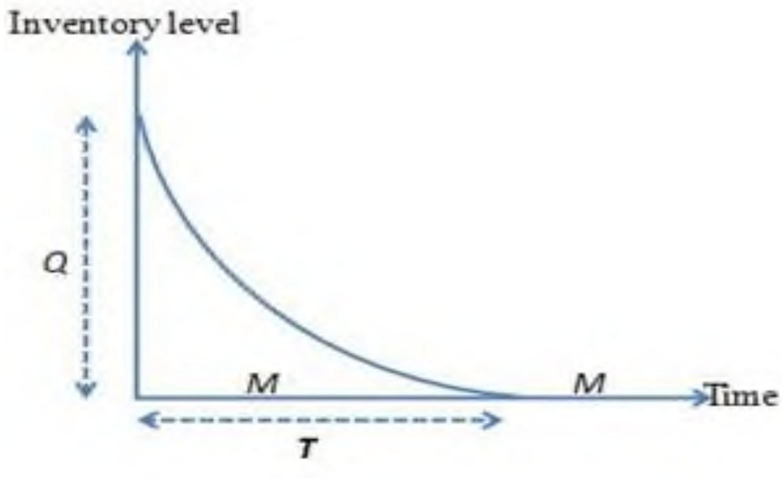

Figure 1. Inventory with time

$$\frac{dl(t)}{dt} + \theta\, l(t) = -D(t),$$

Putting the value of $D(t)$,

$$\frac{dl(t)}{dt} + \theta\, l(t) = -D_o e^{-\alpha t} \qquad 0 \le t \le T \tag{1}$$

The boundary condition are as follows,

$l(0) = Q$ and $l(T) = 0$ (2)

the solution of (1) is given below,

$$l(t) = \frac{D_o}{\theta - \alpha}\left(e^{(\theta - \alpha)T - \theta t} - e^{\theta t} \right), \qquad 0 \le t \le T \tag{3}$$

Using the initial values from eq. (2), the order quantity can be calculated as,

$$Q = l(0) = \frac{D_o}{\theta - \alpha}\left(e^{(\theta - \alpha)T} - 1 \right) \tag{4}$$

Now, the set-up cost (instantaneous) per order due to inflation,

$$OC = \sum_{N=0}^{n-1} O_c e^{Nrt}$$

$$= O_c \left(e^{rH} - 1\right)\left(\frac{1}{rT} + \frac{rT}{4} - \frac{1}{2} \right) \tag{5}$$

The holding cost (instantaneous) per cycle due to inflation,

$$IHC = \frac{D_o\left(h_1 + \frac{h_2}{n^{\beta}} \right)}{\theta - \alpha} \sum_{N=0}^{n-1} O_c e^{Nrt} \int_0^T \left\{ e^{(\theta - \alpha)T - \theta t} - e^{\theta t} \right\} dt$$

$$= \frac{D_o\left(h_1 + \frac{h_2}{n^{\beta}} \right) C_o \left(e^{rH} - 1 \right)\theta T}{r\left(\alpha^2 - \theta^2\right)} \tag{6}$$

Further, the deterioration cost per cycle is given below,

$$DC = Q - \int_0^T - D_o e^{-\alpha t} dt$$

$$= C\left(\frac{D_o}{\theta - \alpha}\left(e^{(\theta - \alpha)T} - 1 \right) + \frac{1}{\alpha}\left(e^{\theta T} - 1\right) \right) \tag{7}$$

$$= \frac{D_o C \theta T^2}{2}$$

The preservation cost per cycle is given as

$PV = \xi T$ (8)

Now, the total cost per cycle,

$$\Psi(T) = \frac{1}{T}\left[IHC + OC + CD + PV - IE + IC \right]$$

Now, Interest charge and interest gain both have calculated in case 1 and case 2, which are given as below:

Case 1: $M \le T$

In the credit period $[0, M]$, the buyer sells the inventory products and deposits the income into an amount bearing account at the interest rate I_e per dollar per year (Figure 2).

Now, the interest gained per unit time is,

$$IE_1 = Ie \sum_{N=0}^{n-1} P(NT) \int_0^M D_o\, e^{-\alpha t} t\, dt$$

$$= P_o D_o Ie \frac{\left(e^{rH} - 1\right)}{2rT}\left(\frac{M^2}{2} - \frac{\alpha}{2} M^3 \right) \tag{9}$$

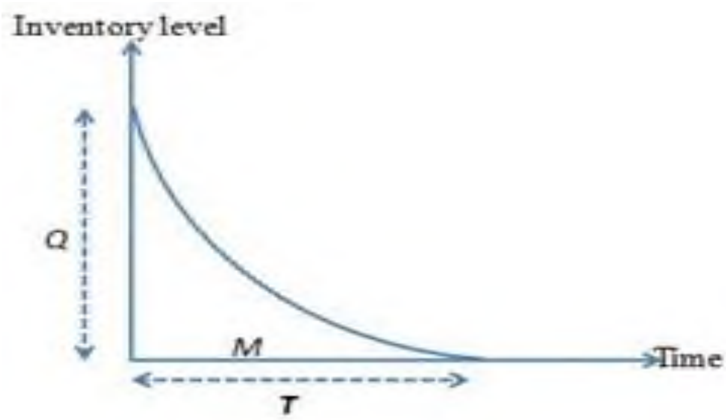

Figure 2. Inventory with time for case 1

Therefore, the interest charged per unit time is,

$$IC_1 = Ip\sum_{N=0}^{n-1} O_c\left(NT\right)\int_M^T l(t)dt = \frac{D_o IpC_0\left(e^{rH}-1\right)}{r\left(\theta^2-\alpha^2\right)}\alpha M\left(\frac{M}{T}-1\right) \tag{10}$$

The total cost per cycle is

$$\Psi_1(T) = \frac{1}{T}\left[OC + IHC + DC + PV + IC_1 - IE_1\right]$$

$$= \frac{1}{T}\left[\begin{array}{l} O_c\left(e^{rH}-1\right)\left(\frac{1}{rT}+\frac{rT}{4}-\frac{1}{2}\right)+\frac{D_o\left(h_1+\frac{h_2}{n^{\beta}}\right)C_o\left(e^{rH}-1\right)\theta T}{r\left(\alpha^2-\theta^2\right)}+\frac{D_o C\theta T^2}{2} \\ +\frac{D_o IpC_0\left(e^{rH}-1\right)}{r\left(\theta^2-\alpha^2\right)}\alpha M\left(\frac{M}{T}-1\right)-P_o D_o Ie\frac{\left(e^{rH}-1\right)}{2rT}\left(\frac{M^2}{2}-\frac{\alpha}{2}M^3\right)+\xi T \end{array}\right] \tag{11}$$

Case 2: $T \le M$ (Figure 3)

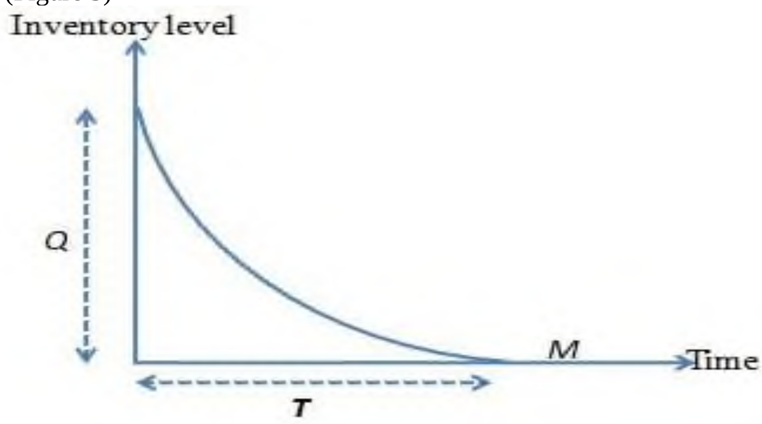

Figure 3. Inventory with time for case 2

In this condition, buyer earns more due to credit period duration and the interest gained per unit is,

$$IE_2 = Ie\sum_{N=0}^{n-1} P\left(NT\right)\left[\int_0^T D_o\, e^{-\alpha t} t\, dt + \left(M-T\right)\int_0^T D_o\, e^{-\alpha t} t\, dt\right]$$

$$= \frac{P_o I_e D_o\left(e^{rH}-1\right)}{r}\left(M - T/2 - \alpha TM/2\right) \tag{12}$$

In this case, total interest charged = 0

Hence, the total cost per time unit is,

$$\Psi_2(T)=\frac{1}{T}\left[OC+IHC+PV+DC+IC_2-IE_2\right]$$

$$\Psi_2(T)=\frac{1}{T}\left[OC+IHC+PV+DC+IC_1-IE_1\right]$$

$$=\frac{1}{T}\left[\begin{array}{l} O_c\left(e^{rH}-1\right)\left(\frac{1}{rT}+\frac{rT}{4}-\frac{1}{2}\right)+\frac{D_o\left(h_1+\frac{h_2}{n^{\beta}}\right)C_o\left(e^{rH}-1\right)\theta T}{r\left(\alpha^2-\theta^2\right)}+\frac{D_oC\theta T^2}{2} \\ -\frac{P_oI_eD_o\left(e^{rH}-1\right)}{r}\left(M-T/2-\alpha TM/2\right) \end{array}\right] \tag{13}$$

3.1 Fuzzification of total cost

If $\tilde{A}=(x_1,x_2,x_3)$ is a triangular fuzzy number, then the centroid method on $\tilde{A}$ is defined as $C\left(\tilde{A}\right)=\frac{x_1+x_2+x_3}{3}$. According to the assumption, the demand rate, purchasing cost and selling price have been considered in imprecise nature. The triangular fuzzy number of demand rate, selling price and purchasing cost are $\tilde{D}_0=(d_1,d_2,d_3)$, $\tilde{P}_0=(p_1,p_2,p_3)$ and $\tilde{C}=(c_1,c_2,c_3)$ respectively. The fuzzification of total cost per unit time for case 1 is calculated from equation (11),

$$\tilde{\Psi}_1(T)=$$

$$=\frac{1}{T}\left[\begin{array}{l} O_c\left(e^{rH}-1\right)\left(\frac{1}{rT}+\frac{rT}{4}-\frac{1}{2}\right)+\frac{\tilde{D}_o\left(h_1+\frac{h_2}{n^{\beta}}\right)C_o\left(e^{rH}-1\right)\theta T}{r\left(\alpha^2-\theta^2\right)}+\frac{\tilde{D}_o\tilde{C}\theta T^2}{2} \\ +\frac{\tilde{D}_oIpC_0\left(e^{rH}-1\right)}{r\left(\theta^2-\alpha^2\right)}\alpha M\left(\frac{M}{T}-1\right)-\tilde{P}_o\tilde{D}_oIe\frac{\left(e^{rH}-1\right)}{2rT}\left(\frac{M^2}{2}-\frac{\alpha}{2}M^3\right)+\xi T \end{array}\right] \tag{14}$$

Now, de- fuzzified the total cost from the equation (14) with the help of centroid method,

$$\tilde{\tilde{\Psi}}_1(T)=\frac{\tilde{\Psi}_{11}+\tilde{\Psi}_{12}+\tilde{\Psi}_{13}}{3} \tag{15}$$

where,

$$\tilde{\Psi}_{11}(T)=$$

$$=\frac{1}{T}\left[\begin{array}{l} O_c\left(e^{rH}-1\right)\left(\frac{1}{rT}+\frac{rT}{4}-\frac{1}{2}\right)+\frac{d_1\left(h_1+\frac{h_2}{n^{\beta}}\right)C_o\left(e^{rH}-1\right)\theta T}{r\left(\alpha^2-\theta^2\right)}+\frac{d_1c_1\theta T^2}{2} \\ +\frac{d_1\,IpC_0\left(e^{rH}-1\right)}{r\left(\theta^2-\alpha^2\right)}\alpha M\left(\frac{M}{T}-1\right)-p_1d_1Ie\frac{\left(e^{rH}-1\right)}{2rT}\left(\frac{M^2}{2}-\frac{\alpha}{2}M^3\right)+\xi T \end{array}\right]$$

$$\tilde{\Psi}_{12}(T)=$$

$$=\frac{1}{T}\left[\begin{array}{l} O_c\left(e^{rH}-1\right)\left(\frac{1}{rT}+\frac{rT}{4}-\frac{1}{2}\right)+\frac{d_2\left(h_1+\frac{h_2}{n^{\beta}}\right)C_o\left(e^{rH}-1\right)\theta T}{r\left(\alpha^2-\theta^2\right)}+\frac{d_2c_2\theta T^2}{2} \\ +\frac{d_2\,IpC_0\left(e^{rH}-1\right)}{r\left(\theta^2-\alpha^2\right)}\alpha M\left(\frac{M}{T}-1\right)-p_2d_2Ie\frac{\left(e^{rH}-1\right)}{2rT}\left(\frac{M^2}{2}-\frac{\alpha}{2}M^3\right)+\xi T \end{array}\right]$$

and

$$\tilde{\Psi}_{13}(T)=$$
$$=\frac{1}{T}\left[\begin{array}{l} O_c\left(e^{rH}-1\right)\left(\frac{1}{rT}+\frac{rT}{4}-\frac{1}{2}\right)+\frac{d_3\left(h_1+\frac{h_2}{n^\beta}\right)C_o\left(e^{rH}-1\right)\theta T}{r\left(\alpha^2-\theta^2\right)}+\frac{d_3c_3\theta T^2}{2} \\ +\frac{d_3\,IpC_0\left(e^{rH}-1\right)}{r\left(\theta^2-\alpha^2\right)}\alpha M\left(\frac{M}{T}-1\right)-p_3d_3Ie\frac{\left(e^{rH}-1\right)}{2rT}\left(\frac{M^2}{2}-\frac{\alpha}{2}M^3\right)+\xi T \end{array}\right]$$

The fuzzification of total cost per unit time for case 2, is calculated from equation (13),

$$\tilde{\Psi}_2(T)=$$
$$=\frac{1}{T}\left[\begin{array}{l} O_c\left(e^{rH}-1\right)\left(\frac{1}{rT}+\frac{rT}{4}-\frac{1}{2}\right)+\frac{\tilde{D}_o\left(h_1+\frac{h_2}{n^\beta}\right)C_o\left(e^{rH}-1\right)\theta T}{r\left(\alpha^2-\theta^2\right)}+\frac{\tilde{D}_o\tilde{C}\theta T^2}{2} \\ -\frac{\tilde{P}_oI_e\tilde{D}_o\left(e^{rH}-1\right)}{r}\left(M-T/2-\alpha TM/2\right) \end{array}\right] \tag{16}$$

Now, de-fuzzified the total cost from the equation (16) for case-2 with the help of centroid method

$$\tilde{\tilde{\Psi}}_2(T)=\frac{\tilde{\Psi}_{21}+\tilde{\Psi}_{22}+\tilde{\Psi}_{23}}{3} \tag{17}$$

where,

$$\tilde{\Psi}_{21}(T)=$$
$$=\frac{1}{T}\left[\begin{array}{l} O_c\left(e^{rH}-1\right)\left(\frac{1}{rT}+\frac{rT}{4}-\frac{1}{2}\right)+\frac{d_1\left(h_1+\frac{h_2}{n^\beta}\right)C_o\left(e^{rH}-1\right)\theta T}{r\left(\alpha^2-\theta^2\right)}+\frac{d_1c_1\theta T^2}{2} \\ -\frac{p_1I_ed_1\left(e^{rH}-1\right)}{r}\left(M-T/2-\alpha TM/2\right) \end{array}\right]$$

$$\tilde{\Psi}_{22}(T)=$$
$$=\frac{1}{T}\left[\begin{array}{l} O_c\left(e^{rH}-1\right)\left(\frac{1}{rT}+\frac{rT}{4}-\frac{1}{2}\right)+\frac{d_2\left(h_1+\frac{h_2}{n^\beta}\right)C_o\left(e^{rH}-1\right)\theta T}{r\left(\alpha^2-\theta^2\right)}+\frac{d_2c_2\theta T^2}{2} \\ -\frac{p_2I_ed_2\left(e^{rH}-1\right)}{r}\left(M-T/2-\alpha TM/2\right) \end{array}\right]$$

and

$$\tilde{\Psi}_{23}(T)=$$
$$=\frac{1}{T}\left[\begin{array}{l} O_c\left(e^{rH}-1\right)\left(\frac{1}{rT}+\frac{rT}{4}-\frac{1}{2}\right)+\frac{d_3\left(h_1+\frac{h_2}{n^\beta}\right)C_o\left(e^{rH}-1\right)\theta T}{r\left(\alpha^2-\theta^2\right)}+\frac{d_3c_3\theta T^2}{2} \\ -\frac{p_3I_ed_3\left(e^{rH}-1\right)}{r}\left(M-T/2-\alpha TM/2\right) \end{array}\right]$$

3.2 Solution process

The numerical results have been calculated with the help of mathematical software Mathematica (version 9). Now, for the minimum cost, first derivative of the cost function should be equal to zero with respect to cycle length.
Using the equation (15) and (17) with necessary condition of optimization, one can find,

$$\frac{\tilde{\tilde{\Psi}}_1(T_1)}{dT_1} = 0 \ and \ \frac{\tilde{\tilde{\Psi}}_2(T_2)}{dT_2} = 0, \tag{18}$$

After calculation, we got the value of $T_1 = \tilde{T}_1 \ and \ T_2 = \tilde{T}_2$ and put these values in the equation (15) and (17), finally got minimum fuzzy total cost per cycle with respect to cycle length. The convexity of total fuzzy cost with respect to cycle length has been proved with the help of graphical method, which is below,

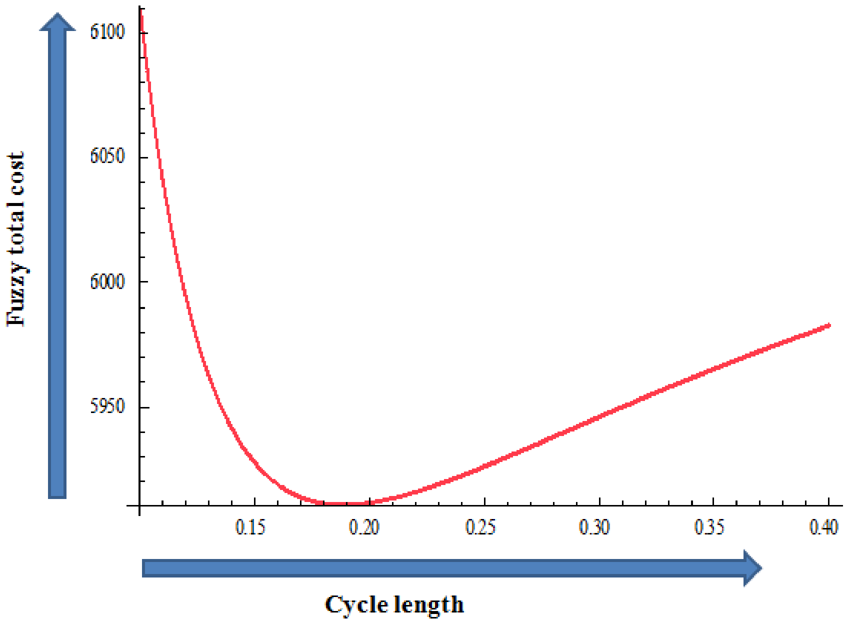

Figure 4. Convexity of fuzzy total cost

3.3 Algorithm

Step 1: Compute $\tilde{T}_1$ and $\tilde{T}_2$ from the equations (15) and (16) with the help of input parameters.

Step 2: If $M \le \tilde{T}_1$, then calculate $\tilde{\tilde{\Psi}}_1(\tilde{T}_1)$, otherwise go to step 3.

Step 3: If $\tilde{T}_2 \le M$, then calculate $\tilde{\tilde{\Psi}}_2(\tilde{T}_2)$, otherwise go to step 4.

Step 4: In this step, it is compared which is better for seller and buyer on the basis of credit period and cycle length as well as total fuzzy cost.

4. NUMERICAL EXAMPLE

Some of the input parameters are considered from Aggarwal et al. (2017) and Jayaswal et al. (2019),

$\tilde{D}_0 = (145,\ 150,\ 155), h_1 = 2, h_2 = 1, c_1 = 30, c_2 = 10, \beta = 0.23, \theta = 0.20, \xi = 0.15 /$ items,

$\text{Ie} = \$0.14/\$/\text{ year}$, $Ip = \$0.15/\$/yaer$, $H = 1$, $\tilde{C} = (15,\ 20,\ 25)$, $\tilde{P}_o = (20,\ 25,\ 30)$,

$M = 15/365$ year, $\text{r} = 0.01$, fuzzy optimal cycle length, $\tilde{\text{T}}_1 = 0.1600$ year

and minimum total fuzzy cost $\tilde{\tilde{\Psi}}_1(\tilde{T}_1) = 5929\ \$/\text{year}$

5. SENSITIVITY ANALYSIS

The effects on the cycle length and total cost per cycle over the number of shipments, learning rate, trade credit, deterioration rate and preservation cost has been sensitively analyzed below in the Tables (1-6).

Table 1. Impact of inflation rate on cycle time and total fuzzy cost per cycle

Inflation rate (r)	Cycle length $\tilde{T}_1$ (Year)	Retailer's total cost $\tilde{\tilde{\Psi}}_1(\tilde{T}_1)$ in ($)
0.01	0.1600	5929
0.02	0.1599	5954
0.03	0.1599	5979
0.04	0.1599	6004
0.05	0.1598	6030

Table 2. Impact of the number of shipments on cycle time and total* fuzzy cost

Number of shipments (n)	Cycle length $\tilde{T}_1$ (year)	Retailer's total cost $\tilde{\tilde{\Psi}}_1(\tilde{T}_1)$ ($)
1	0.1603	6720
2	0.1602	6337
3	0.1601	6144
4	0.1601	6019
5	0.1600	5929

Table 3. Impact of the credit period on cycle time and whole fuzzy cost

Credit period M (year)	Cycle time $\tilde{T}_1$ (Year)	Retailer's total cost $\tilde{\tilde{\Psi}}_1(\tilde{T}_1)$ ($)
0.0411	0.1600	5929
0.0547	0.1202	5662
0.0685	0.0960	5320
0.0822	0.0802	4920

Table 4. Impact of the fuzzy selling price on retailer's cycle time and whole fuzzy cost

Fuzzy selling price $\tilde{P}_0$	Cycle length $\tilde{T}_1$ (year)	Retailer's total cost $\tilde{\tilde{\Psi}}_1(\tilde{T}_1)$ ($)
$(20, 25, 30)$	0.1600	5929.12
$(25, 30, 35)$	0.1600	5929.47
$(30, 35, 40)$	0.1600	5929.79

Table 5. Impact of the fuzzy purchasing cost on retailer's cycle time and whole fuzzy cost

Fuzzy purchasing cost ($)	Cycle length $\tilde{T}_1$ (year)	Retailer's total cost $\tilde{\tilde{\Psi}}_1\left(\tilde{T}_1\right)$ ($)
$(5,10,15)$	0.1602	5927
$(10,15,20)$	0.1601	5928
$(15,20,25)$	0.1600	5929

Table 6. Impact of the fuzzy demand rate on retailer's cycle time and whole fuzzy cost per cycle

Fuzzy demand rate	Cycle length $\tilde{T}_1$ (year)	Retailer's total cost $\tilde{\tilde{\Psi}}_1\left(\tilde{T}_1\right)$ ($)
$(145,150,155)$	0.1600	5929
$(195,200,205)$	0.1201	7752
$(245,250,255)$	0.0962	9500

Managerial insights

1. From Table-1, if inflation rate increases, cycle length decreases and retailer's total cost increases.
2. From Table-2, if the number of shipments increases, cycle length less decreases and retailer's cost decreases.
3. From Table-3, if M increases then cycle length and retailer's total cost decrease.
4. From Table-4, if fuzzy selling price increases, cycle length decreases, and retailer's cost marginally increases.
5. From Table-5, if fuzzy purchasing cost increases then, cycle length decreases and retailer's total cost less increases.
6. From Table-6, if fuzzy demand rate increases then, cycle length decreases and retailer's total cost increases.

5.1 Discussion part

It is concluded that the minimum cost is given by Case-1 which is $M \leq T$ and seems that it is beneficial due to the suitable credit period which have obtained from the algorithm and other cases are not considered due to the large value of credit period which have been analyzed from the algorithm.

6. CONCLUSION

The present scenario is tried to develop a mathematical formula to determine cycle length and the corresponding fuzzy total cost for the buyer with trade credit financing, inflation under learning environment. Learning effect controls the number of shipments. When items are perishable then preservation should be must to control the deterioration rate but the total fuzzy cost increases annually. The total fuzzy cost is changed when demand rate, selling price and purchasing cost are imprecise in nature. Defuzzification process is very helpful when some of the inventory parameters are imprecise in nature and released positive results for present scenario which already have been analyzed in sensitivity analysis section. Present work can be extended for many sensible positions such as cloudy fuzzy system and two-level trade-credit policies, carbon emissions, three echelon supply chain etc. The present model can be further enhanced for imperfect quality items.

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