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AN INVENTORY MODEL FOR DETERIORATING ITEMS WITH MULTIVARIATE DEMAND AND TRADE CREDIT

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ABSTRACT. In this paper, an inventory model is developed to maximize the total average profit. The rate of deterioration is taken as fixed. The effect of inflation is also considered in this present paper. The demand rate is assumed to be price and stock dependent. Shortages are allowed and partially backlogged. The backlogging rate is assumed to be dependent on weighting time. Numerical examples and sensitivity analysis are presented to illustrate the result of the proposed model.

1. INTRODUCTION

Every business or organization is based on demand. It directly affects the Economic Growth of any organization. The success of a business depends on the factor that how efficiently one can fulfill the demand of the customers. In the beginners, model demand was taken as constant, but practically this is not possible. Demand can of different types like short-term demand or long-term demand, individual or organization demand, market dependent, dependent, independent demand, price dependent or stock dependent, etc. Stock dependent demand is mainly associated with the stock available in hand. It always affects the popularity or goodwill of a product. The best example can be easily seen in the mall or supermarket. If the stock of any product is high in any supermarket

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that shows the popularity or high demand for it, on revert the low level of the product shows the less demand for the particular product. Gupta and Vrat [9] were the first ones, who developed a model for stock dependent demand. This model was further modified by Mandal and Phaujdar [10] by taking the stock dependent demand for deteriorating items. After these many researchers show their interest in stock dependent demand and gave their work in this. For example, Pal et. al. [15], Sana and Chaudhary [18], Giri [7], Ray et. al. [16], Ray and Choudhari [17], Amutha and Chandrasekaran [2] etc give their different inventory model for Stock dependent demand. Chang et. al. [5] generates their optimal replenishment policies for the same. Sana [19] developed inventory model stock dependent demand for perishable products. Gupta et. al. [9] developed their model for non-instantaneous products. Vipin and Anupma [25] developed an inventory model by using preservation technology for deteriorating items with parabolic holding cost. Gopal and Vipin [8] developed a cost minimization policy for deteriorating in the Inflationary environment with partial backlogging.

In the classical time, the payment of the items was done exactly at the time of delivery or before it. But in the modern era, as the business is getting huge and complex, this practice is not possible. Nowadays, the retailer need not clear his dues at the time of delivery. Now Trade Credit is also known as permissible delay in payment, the practice followed by every business. In this, a grace period is provided by the supplier to his retailers to complete the payment. During this phase, the retailer need not pay any interest for the amount. S. K. Goyal [20] developed an inventory model with the permissible delay in payment. S. P. Agarwal and C. K. Jaggi [21] developed ordering policies for deteriorating items with the allowed delay in payment. That was further followed S. W. Shinn and Hwang [22], Jamal, B. R. Sarkar, S. Wang [1], J. T. Teng [11], K. J. Chung and Hwang [4] by developing different models with trade credit. During the last few years, the researchers developed the models with new ideas like Jaggi and Tiwari [13] focused on price-dependent demand for non-instantaneous under permissible delay in payment. Das and Roy [6] used the tread credit policy for multi warehouses with inflation. Bhunia et al. [3] discussed the inventory model for two warehouses via particle swarm. Saxena and Singh [23] developed a model to show the coordination between vendor and buyer for remanufacturing items. Tiwari et al. [24] show the impact of tread credit for two warehouses for the non-instantaneous deteriorating items under inflation. Rastogi and Singh [14] developed a model under tread credit with variable holding cost and cash discount policy. Jaggi et al. [12] use the credit finance policy for two warehouses in there EOQ model for deteriorating items.

In the article, An EOQ model is created with multivariate interest where deficiencies are allowable and somewhat accumulated. The rate of disintegration is two-parameter Weibull distribution. Additionally, the holding cost is expanding. Retailers are given a fixed time advance to be paid by the distributor to build advertise requests and benefits. This strategy is additionally remembered for the model. Which is a commonsense circumstance. Numerical models have additionally been taken to show the model graphically. The network of the benefits work is shown by the figure to guarantee the presence of a one of a kind ideal arrangement. Toward the finish of the model, the affectability of the absolute benefit is additionally demonstrated comparative with the principle parameters of the framework. The primary goal of making this paper is a stock model where the complete normal benefit will be amplified.

After the introduction part, the proposed model is composed in the following way: In second part, the supposition and notations are depicted, which are utilized all through this model. The scientific formulation and solution are built up in segment part. Part IV gives the numerical model illustration by the graph. The last section shows the sensitivity regarding key parameters of the model.

2. Assumptions And Notations

The following are the notations and assumptions.

2.1. Notations.

- **i** T The length of the cycle time.
- **ii** t_1 the time where the positive inventory level become zero
- **iii** A Ordering cost/order.
- **iv** C_1 Purchase cost/unit.
- **v** C_2 Backordered cost/unit short/unit time.
- **vi** C_3 Cost of lost sales/unit.
- **vii** $I = IM + BM$: Order quantity during a cycle of length T
- **viii** IM Maximum inventory units

ix BM Maximum back ordered units during stock out period.
x $I_1(t)$ Level of positive inventory at the time $t,\ 0 \leq t \leq t_1$
xi $I_2(t)$ Level of negative inventory at the time $t,\ t_1 \leq t \leq T$
xii $P(t_1, s)$: Total profit per unit time.

2.2. **Assumptions.**

i The planning horizon is infinite.
ii Lead time is zero.
iii The demand rate $D(t,s) = \begin{cases} a + bI(t) - s, & I(t) \geq 0 \\ a - s, & I(t) \leq 0 \end{cases}$, where $a > 0$, $0 < b << 1$, $a > s$ and s is selling price.
iv The rate of deterioration $\theta(t) = \alpha\beta t^{\beta-1}$ where the scale parameter is $0 < \alpha < 1$ and the shape parameter $\beta > 0$.
v The backlogging rate $B(t) = \frac{1}{1+\delta(T-t)}$; $\delta > 0$ is backlogging parameter and $t_1 \leq t \leq T$ which is waiting for time length dependent for the next replenishment.
vi Holding cost is assumed to be $h(t) = h_1 + h_2 t$, where $h_1 > 0$, and $h_2 > 0$. which is time-dependent per unit per unit time.
vii Instantaneous Replenishment rate.

3. Mathematical Formulation And Solution

Under the above assumption, the inventory system is developed as follows: the total cycle interval $[0, T]$ divided into two subintervals $[0, t_1]$ and $[t_1, T]$. In the first subinterval $[0, t_1]$ shows the a decrement in inventory level due to combined effects of demand and deterioration and this decrement reaches to level zero at the time t_1. The second subinterval $[t_1, T]$ demonstrates the shortages which occur from or after time t_1 and due to partial backlogging some demand are lost as shown in Figure 1.

The differential equation (3.1) shows the state of inventory level at any time t during the subinterval $[0, t_1]$ and the differential equation (3.2) represent the state of inventory level at any time t during the second subinterval $[t_1, T]$

$$\frac{dI_1(t)}{dt} = -\alpha\beta t^{\beta-1} I_1(t) - (a + bI_1(t) - s), 0 \leq t \leq t_1, \tag{3.1}$$

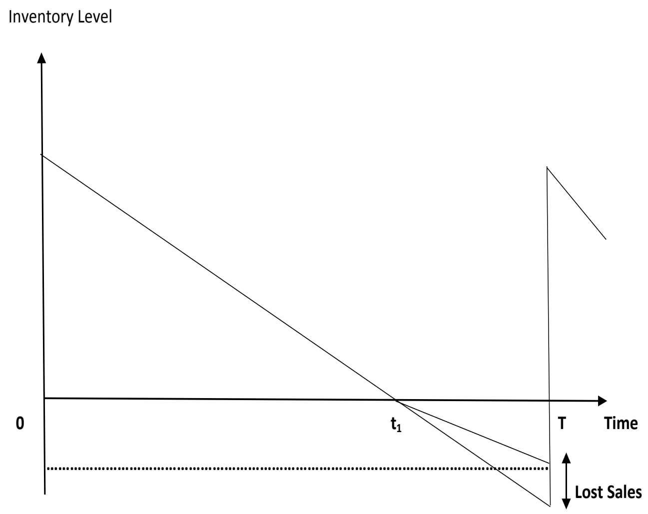

FIGURE 1

with boundary condition $I_1\left(t_1\right)=0$.

(3.2) $$\frac{dI_2\left(t\right)}{dt}=-\left(a-s\right)B\left(t\right),t_1\leq t\leq T\,,$$

with boundary condition $I_2\left(t_1\right)=0$.

The solution of (3.1) and (3.2) are given by

$$I_1\left(t\right)=\left(a-s\right)\left[\begin{array}{l}\left(t_1-t\right)\left\{\frac{b}{2}\left(t_1+t\right)+1-bt-\alpha t^{\beta}\right\}\\+\frac{\alpha}{\beta+1}\left(t_1^{\beta+1}-t^{\beta+1}\right)\end{array}\right]$$

$$I_2\left(t\right)=\frac{\left(a-s\right)}{\delta}In\left[\frac{1+\left(T-t\right)\delta}{1+\left(T-t_1\right)\delta}\right]\,.$$

The maximum positive inventory is

$$IM=I_1\left(0\right)=\left(a-s\right)\left[\frac{\alpha}{\beta+1}t_1^{(\beta+1)}+\frac{b}{2}t_1^2+t_1\right]\,.$$

The maximum back orders

$$BM=-I_2\left(T\right)=\frac{\left(a-s\right)}{\delta}In\left[1+\left(T-t_1\right)\delta\right]\,.$$

Hence the order size during $[0,T]$ given by

$$I=\left(a-s\right)\left[\begin{array}{l}t_1+\frac{b}{2}t_1^2+\frac{\alpha}{\beta+1}t_1^{(\beta+1)}\\+\frac{1}{\delta}In\left[1+\delta\left(T-t_1\right)\right]\end{array}\right]\,.$$

The following cost per cycle is calculated for the total profit.

Ordering cost

$$OC = A\,.$$

Inventory holding cost

$$\begin{aligned} HC &= \int_0^{t_1} (h_1 + h_2 t)\, I_1(t)\, dt \\ &= (a-s)\left[\begin{array}{l} h_1 t_1^2 \left\{ \frac{t_1^\beta \alpha\left((\beta+1)^2-\alpha\right)}{(\beta+1)^2(\beta+2)} + \frac{(3(\beta+1)+bt_1(2\beta-\alpha+2))}{6(\beta+1)} \right\} \\ +h_2 t_1^3 \left\{ \frac{t_1^\beta \alpha((\beta+1)(\beta+2)-2\alpha)}{2(\beta+1)(\beta+2)(\beta+3)} + \frac{1}{6} + bt_1\left(\frac{1}{8} - \frac{\alpha}{12(\beta+1)}\right) \right\} \end{array}\right]. \end{aligned}$$

Backordered cost

$$\begin{aligned} BC &= C_2 \int_{t_1}^{T} -I_2(t)\, dt \\ &= C_2 \frac{(a-s)}{\delta}\left(T - t_1 + \frac{1}{\delta}\log\left[\frac{1}{1+\delta(T-t_1)}\right]\right). \end{aligned}$$

Lost sales cost

$$\begin{aligned} LSC &= C_3 \int_{t_1}^{T} [1 - B(t)]\, D(t)\, dt \\ &= \frac{C_3(a-s)}{\delta}\left((T-t_1)\delta - \log\left[1+\delta(T-t_1)\right]\right). \end{aligned}$$

Purchase cost

$$PC = C_1 \times I = C_1\left[(a-s)\left[t_1 + \frac{b}{2}t_1^2 + \frac{\alpha}{\beta+1}t_1^{(\beta+1)} + \frac{1}{\delta}In\left[1+\delta(T-t_1)\right]\right]\right].$$

Sales revenue

$$\begin{aligned} SR &= s\int_0^{t_1}(a + bI(t) - s)\, dt + s\int_{t_1}^{T}(a-s)\, dt \\ &= (a-s)\, s\left[T + b\left(\frac{1}{6}t_1^2(3+2bt_1) + \frac{\alpha}{\beta+1}\left(\frac{t_1^{\beta+2}\left((1+\beta)^2-\alpha\right)}{(\beta+1)(\beta+2)} - \frac{bt_1^3}{6}\right)\right)\right]. \end{aligned}$$

Case I $M \le t_1$, In this case, the wholesaler provides time for Retailer to deposit all its dues on the inventory end or before.

Interest payable

The interest payable IP per cycle

$$\begin{aligned} IP_1 &= pI_p \int_M^{t_1} I(t)\, dt \\ &= pI_p(a-s)\left(\begin{array}{l} \frac{M^2}{2} + \frac{bM^3}{6} - Mt_1 + \frac{v^2}{2} - \frac{1}{2}bMt_1^2 + \frac{bt_1^3}{3} \\ -\frac{\alpha}{\beta+1}\left(\begin{array}{l} t_1^2\left(\frac{bt_1}{6} - \frac{t_1^\beta\left((\beta+1)^2-\alpha\right)}{(\beta+1)(\beta+2)}\right) \\ \frac{1}{6}M\left(\begin{array}{l} bM(2M-3t_1) \\ +6\left(t_1^{\beta+1} - \frac{M^\beta t_1 \alpha}{\beta+1} + \frac{M^{1+\beta}(\alpha-1)}{\beta+2}\right) \end{array} \right) \end{array} \right) \end{array} \right) \end{aligned}$$

Interest earned

The interest earned IE_1 per cycle

$$\begin{aligned} IE_1 &= sI_e \int_0^{t_1} D(t)\, t dt \\ &= (a-s)\, st_1^2 I_e \left(\begin{array}{l} \frac{\left(12+4bt_1+3b^2t_1^2\right)}{24} - \frac{\alpha b^2 t_1^2}{12(\beta+1)} \\ -\frac{bt_1^{1+\beta}\alpha(2\alpha-(\beta+1)(\beta+2))}{2(\beta+1)(\beta+2)(\beta+3)} \end{array} \right) \end{aligned}$$

Case II $M \geq t_1$, In this case, the wholesaler gives time to Retailer to deposit all its dues after the inventory is exhausted completely.

Interest payable

In this case, the interest payable per cycle is zero, since the retailer has sold out the entire stock bought on credit from the supplier i.e.,

$$IP_2 = 0$$

Interest earned

In this case, the interest earned IE_2 per cycle

$$\begin{aligned} IE_2 &= sI_e\left[\int_0^{t_1} D(t)\, t dt + (M-t_1)\int_0^{t_1} D(t)\, dt\right] \\ &= sI_e(a-s)\left[\begin{array}{l} t_1^2\left(\begin{array}{l} \frac{-bt_1^{1+\beta}\alpha(2\alpha-(\beta+1)(\beta+2))}{2(\beta+1)(\beta+2)(\beta+3)} \\ +\frac{(12(\beta+1)+bt_1(4(\beta+1)+bt_1(3-2\alpha+3\beta)))}{24(\beta+1)} \end{array} \right) \\ +(M-t_1)\left(t_1 + b\left(\begin{array}{l} \frac{1}{6}t_1^2(3+2bt_1) \\ +\frac{\alpha}{\beta+1}\left(-\frac{bt_1^3}{6} + \frac{t_1^{\beta+2}\left(-\alpha+(\beta+1)^2\right)}{(\beta+1)(\beta+2)}\right) \end{array} \right)\right) \end{array} \right] \end{aligned}$$

The total average profit of the system per unit time is given by

$$Max\left[TP\left(t_1,s\right)\right]=\begin{cases}TP_1\left(t_1,s\right),M\leq t_1\\TP_2\left(t_1,s\right),M\geq t_1\end{cases}$$

$$\text{where } TP_1=\frac{1}{T}\left[SR-OC-HC-SC-LSC-PC-IP_1+IE_1\right],$$

and

$$TP_2=\frac{1}{T}[SR-OC-HC-SC-LSC-PC-IP_2+IE_2],$$

where $TP_1\left(p,t_1\right)$ and $TP_2\left(p,t_1\right)$ are discussed as follows:

4. Solution Procedure

We solve the above-mentioned problem using the following algorithm.

Step 1. Input the value of all the required parameters of the proposed inventory model.

Step 2. In order to find the optimal value $t_1{}^*$, s^* to maximize the total average profit $TP_i\,(i=1,2)$.

First, we differentiate $TP_i\,(i=1,2)$ and find out $\frac{\partial TP_i}{\partial t_1}\,\frac{\partial TP_i}{\partial s}\,\frac{\partial^2 TP_i}{\partial t_1^2}\,\frac{\partial^2 TP_i}{\partial s^2}\,\frac{\partial^2 TP_i}{\partial t_1\partial s}$ where $i=1,2$.

The optimal value of $t_1{}^*$, s^* can be obtained by solving the following equations, $\frac{\partial TP_i}{\partial t_1}=0$ and $\frac{\partial TP_i}{\partial s}=0$ where $i=1,2$.

Using the software Mathematica we get $t_1{}^*$, s^*. Evaluate $\frac{\partial^2 TP_i}{\partial t_1^2}\frac{\partial^2 TP_i}{\partial s^2}$ and $\frac{\partial^2 TP_i}{\partial t_1\partial s}$ for the value of $t_1{}^*$, and s^*.

The necessary and sufficient condition for maximization is:

$$\left(\frac{\partial^2 TP_i}{\partial t_1^2}\right)\left(\frac{\partial^2 TP_i}{\partial s^2}\right)-\left(\frac{\partial^2 TP_i}{\partial t_1\partial s}\right)^2>0$$

and

$$\frac{\partial^2 TC_i}{\partial t_1^2}<0\frac{\partial^2 TC_i}{\partial s^2}<0\,.$$

Since the nature of the profit function is highly nonlinear, thus the concavity of the function is shown in the next section.

Step 3. Stop.

5. NUMERICAL ILLUSTRATIONS

Example 1. *Consider the following data in appropriate units to illustrates the inventory system* $A = 600$, $a = 120$, $b = 0.02, C_1 = 20, C_2 = 30, C_3 = 50$, $M = 0.6, \alpha = 0.02, \beta = 4, h_2 = 4, h_1 = 0.6, \delta = 0.6, T = 1, I_p = 0.2, I_e = 0.04$.

Then we get the optimum values of $s^* = 69.8501$, $t_1{}^* = 0.8604$, $Q^* = 952.988$ $TP^* = 1971.37$

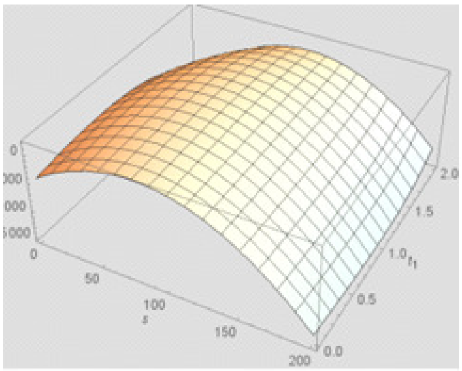

FIGURE 2

Example 2. *Consider the following data in appropriate units to illustrates the inventory system* $A = 600$, $a = 120$, $b = 0.02$, $C_1 = 20$, $C_2 = 30$, $C_3 = 50$, $M = 0.95$, $\alpha = 0.02$, $\beta = 4$, $h_1 = 0.6$, $h_2 = 4$, $\delta = 0.6$, $T = 1$, $I_p = 0.2$ *and* $I_e = 0.4$.

Then we get the optimum values of $s^* = 69.7741$, $t_1{}^* = 0.8178$ $Q^* = 952.988$ $TP^* = 1984.68$

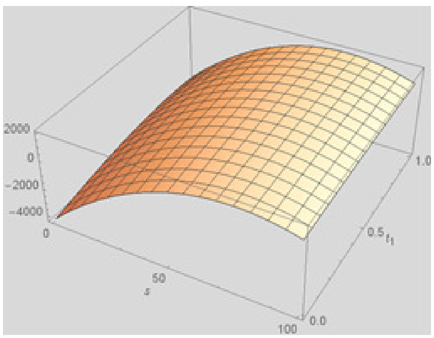

FIGURE 3

6. Sensitivity Analysis

Using the above numerical examples, we will study the effect on the result by changing the parameter and to reduce the length of paper here we discussed only case I

Parameter	% Change	Parameter Value	t_1	s	TP
A	-50%	300	0.8604	69.8501	2271.37
	-25%	450	0.8604	69.8501	2121.37
	25%	750	0.8604	69.8501	1821.37
	50%	900	0.8604	69.8501	1671.37
a	-50%	60	0.827	39.823	-814.35
	-25%	90	0.8435	54.8318	663.43
	25%	150	0.8776	84.8758	3740.06
	50%	180	0.8952	99.9095	5970.16
C_1	-50%	10	0.9478	65.2347	2480.9
	-25%	15	0.9065	67.5649	2217.88
	25%	25	0.8084	72.0832	1741.41
	50%	30	-	-	-
C_2	-50%	15	-	-	-
	-25%	22.5	0.8356	69.779	1975.44
	25%	37.5	0.8786	69.9093	1968.34
	50%	45	0.8926	69.9446	1966
C_3	-50%	25	0.8	69.679	1981.21
	-25%	37.5	0.8356	69.779	1975.44
	25%	62.5	0.8786	69.9033	1968.34
	50%	75	0.8926	69.9446	1966
α	-50%	0.01	-	-	-
	-25%	0.015	0.8616	69.8468	1971.85
	25%	0.025	0.8592	69.8534	1970.89
	50%	0.03	0.858	69.8567	1969.41
β	-50%	2	-	$-$	-
	-25%	3	0.8596	69.8578	1970.5
	25%	5	0.8611	69.8455	1971.91
	50%	6	0.8616	69.8426	1972.27

Parameter	% Change	Parameter Value	t_1	s	TP
b	-50%	0.01	0.8508	69.8377	1961.98
	-25%	0.15	0.8555	69.8436	1966.63
	25%	0.25	-	-	-
	50%	0.3	0.8703	69.8648	1981.13
h_1	-50%	0.2	0.8644	69.8177	1975.23
	-25%	0.3	0.8624	69.834	1973.29
	25%	0.5	0.8584	69.8662	1969.45
	50%	0.6	0.8564	69.8822	1967.55
h_2	-50%	2	0.8773	69.7633	1982.54
	-25%	3	0.8687	69.8073	1976.87
	25%	5	0.8223	69.8919	1966.03
	50%	6	0.8445	69.9326	1960.84
δ	-50%	0.3	0.6764	68.877	2049.67
	-25%	0.45	0.7788	69.46	2001.14
	25%	0.75	0.9271	70.1009	1954.78
	50%	0.9	0.9829	70.2455	1948.04
I_p	-50%	0.1	0.8606	69.8497	1971.44
	-25%	0.15	0.8605	69.8499	1971.4
	25%	0.25	0.8603	69.8503	1971.33
	50%	0.3	0.8601	69.8505	1971.3
I_e	-50%	0.02	0.8345	69.8927	1946.07
	-25%	0.03	0.8474	69.8703	1958.52
	25%	0.05	-	-	-
	50%	0.06	0.887	69.8169	1998.27
M	-50%	0.3	0.8599	69.85	1970.87
	-25%	0.45	0.8601	69.8518	1971.16
	25%	0.75	0.8606	69.9494	1971.48
	50%	0.9	0.8609	69.8495	1971.5

7. Observations

By the above sensitive table we see that

i If the system parameters A, h_1, h_2, δ and I_p are increases then the total profit is decreasing.

ii If the system parameters a, b, β, I_e and M are increases then the total profit is also increasing.

8. CONCLUSION

In this paper, an EOQ model is created for deteriorating items with multivariate demand under trade credit facility by the provider to the client under the two distinct cases. The case I deal with where the total inventory level expires on or before the trade credit period time. Case II deals with where the trade credit period is greater than where the stock level exhausts up to zero. Holding cost is time dependent and unsatisfied demands are backlogged. Numerical models are given to represent the outcome. Numerical examples are given to illustrate the result. Sensitivity analysis with respect to various parameters of the model has also been demonstrated.

REFERENCES

[1] A. M. M. JAMAL, B. R. SARKER, S. WANG: *An Ordering Policy for Deteriorating Items with Allowable Shortage and Permissible Delay in Payment August 1997*, Journal of the Operational Research Society, **48**(8) (1997), 826–833.

[2] R. AMUTHA, E. CHANDRASEKARAN: *An EOQ Model for Deteriorating Items with Quadratic Demand and Time-Dependent Holding Cost*, International Journal of Emerging Science and Engineering, **1**(5) (2013), 5–6.

[3] A. K. BHUNIA, A. A. SHAIKH, L. SAHOO: *A two-warehouse inventory model for the deteriorating item under permissible delay in payment via particle swarm optimization*, International Journal of Logistics Systems and Management, **24**(1) (2016), 45–69.

[4] K. J. CHUNG, Y. F. HUANG: *The optimal cycle time for EPQ inventory model under permissible delay in payments*, International Journal of Production Economics, **84**(3) (2003), 307–318.

[5] C. T. CHANG, J. T. TENG, S. K. GOYAL: *Optimal replenishment policies for non-instantaneous deteriorating items with stock-dependent demand*, International Journal of Production Economics, **123** (2010), 62–68.

[6] D. DAS, A. ROY, S. KAR, : *A multi-warehouse partial backlogging inventory model for deteriorating items under inflation when a delay in payment is permissible*, Annals of Operations Research, **226**(1) (2015), 133–162.

[7] B. C. GIRI, S. PAL, A. GOSWAMI, K. S. CHAUDHURI: *An inventory model for deteriorating items with stock-dependent demand rate*, European Journal of Operational Research, **95** (1996), 604–610.

[8] G. PATHAK, V. KUMAR, C. B. GUPTA: *A Cost Minimization Inventory Model for Deteriorating Products and Partial Backlogging under Inflationary Environment Global*, Journal of Pure and Applied Mathematics, **13** (2017), 5977–5995.

[9] R. GUPTA, P. VRAT: *An inventory model with multi-items under constraint systems for stock dependent consumption rate*, Operations Research, **24** (1986), 41–42.

[10] B. N. MANDAL, S. PHAUJDAR: *An inventory model for deteriorating items and stock dependent consumption rate*, Journal of the Operational Research Society, **40** (1989), 483–488.

[11] J. T. TENG: *Deterministic economic order quantity models with partial backlogging when demand and cost are fluctuating with time*, Journal of the Operational Research Society, **55**(5) (2002), 495–503.

[12] C. K. JAGGI, A. SHARMA, S. TIWARI: *Credit financing in economic ordering policies for non-instantaneous deteriorating items with price dependent demand under permissible delay in payments: A new approach*, International Journal of Industrial Engineering Computations, **6**(4) (2015), 481–502.

[13] C. K. JAGGI, S. TIWARI, S. K. GOEL: *Credit financing in economic ordering policies for non-instantaneous deteriorating items with price dependent demand and two storage facilities*, Annals of Operations Research, **248**(1) (2017), 253–280.

[14] M. RASTOGI, S. R. SINGH, P. KUSHWAH, S. TAYAL: *An EOQ model with variable holding cost and partial backlogging under credit limit policy and cash discount*, Uncertain Supply Chain Management, **5** (2017), 27–42.

[15] S. PAL, A. GOSWAMI, K. S. CHAUDHURI: *A deterministic inventory model for deteriorating items with stock-dependent demand rate*, International Journal of Production Economics, **32** (1993), 291–299.

[16] J. RAY, A. GOSWAMI, K. S. CHAUDHURI: *On an inventory model with two levels of storage and stock-dependent demand rate*, International Journal of Systems Science, **29** (1998), 249–254.

[17] T. ROY, K. S. CHAUDHURI: *A production-inventory model under stock-dependent demand, Weibull distribution deterioration, and shortage*, Intl. Trans. in Op. Res., **16** (2009), 325–346.

[18] S. SANA, K. S. CHAUDHARY: *A Stock-Review EOQ Model with Stock-Dependent Demand, Quadratic Deterioration Rate*, Adv Modeling and Optimization, **6**(2) (2004), 25–32.

[19] S. S. SANA: *An EOQ model for the perishable item with stock-dependent demand and price discount rate*, American Journal of Mathematical and Management Sciences, **30**(3-4) (2004), 299–316.

[20] S. K. GOAL: *Economic order quantity under conditions of permissible delay in payments*, Journal of Operational Research, **36** (1985), 335–338.

[21] S. P. AGGARWAL, C. K. JAGGI: *Ordering Policies of Deteriorating Items under Permissible Delay in Payments*, Journal of the Operational Research Society, **46**(5) (1995), 658–662.

[22] S. W. SHINN, H. HWANG, S. S. PARK: *Joint price and lot size determination under conditions of permissible delay in payments and quantity discounts for freight cost European*, Journal of Operational Research, **91**(3) (1996), 528–542.

[23] N. SAXENA, S. R. SINGH, S. S. SANA: *A green supply chain model of vendor and buyer for remanufacturing items*, RAIRO-Operations Research, **51**(4) (2006), 1133–1150.

[24] S. TIWARI, L. E. CÁRDENAS-BARRÓN, A. KHANNA, C. K. JAGGI: *Impact of trade credit and inflation on retailer's ordering policies for non-instantaneous deteriorating items in a two-warehouse environment*, International Journal of Production Economics, **176** (2016), 154–169.

[25] V. KUMAR, A. SHARMA, C. B. GUPTA: *An EOQ Model For Time-Dependent Demand and Parabolic Holding Cost With Preservation Technology Under Partial Backlogging For Deteriorating Items*, International Journal of Education and Science Research Review, **1**(2) (2014), 170–185.

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