INDIAN JOURNAL OF SCIENCE AND TECHNOLOGY

RESEARCH ARTICLE

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OPEN ACCESS

Received: 05-05-2024

Accepted: 13-07-2024

Published: 01-08-2024

Citation: Das SC (2024) Low Financing Trade Credit Inventory for High Deterioration under Time Dependent Holding Cost. Indian Journal of Science and Technology 17(30): 3093-3099. https://doi.org/10.17485/IJST/v17i30.1516

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Funding: None

Competing Interests: None

Published By Indian Society for Education and Environment (iSee)

ISSN
Print: 0974-6846
Electronic: 0974-5645

Low Financing Trade Credit Inventory for High Deterioration under Time Dependent Holding Cost

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Abstract

Objective: Rented house owners are take policy ensure their rent for a certain period for contract of rent. Due to pandemic situation, people have of less capital and are not possible to take high decision in business. Also, many of the food products are stored in high preservation, however when a food product collected out from preservative condition high rate of deterioration are seen among foods. **Method:** Lower capital feature of society force to consider an inventory system for three-parameter Weibull distributed deterioration, lees capital and borrowing of item from a greater business organization. Also, for security period of rent, new type of holding is considered in the proposed inventory model. Due to consideration of three-parameter Weibull distribution deterioration objective functions are highly nonlinear and to solve the optimization problems three types of quantum behaved particle swarm optimization technique applied. **Findings:** Gaussian behaved particle swarm optimization (GQPSO) technique gives better optimum than other techniques. A sensitivity analyses about some inventory parameters are shown in figures and fruitful managerial insight features are given for the model. Man power management in a business and duration of business period effects directly to profit. **Novelty:** Holding cost is constant for a period of time then linearly time dependent. This type of holding cost is a new concept in the literature. Discount on selling price is considered when items are started to deteriorated. Also, purchase cost paid at the end of business period and free from any interest charge.

Keywords: NonInstantaneous Deterioration; Stock Level; Trade Credit; TimeVarying Holding Cost; Low Finance; Weibull Distribution

1 Introduction

Large business organization sales their items through various agent or vendor counter. However, many people bargaining to local ruler for market place in their locality. Their capital for business is very small. These types of retailer are borrowing item from local supplier to make vendor counter. Also, just after end of business period total purchase cost paid by the retailer. It is two side gains in business, supplier minds on stocks and retailer minds on business vendor. These situations are found in various town or city.

Trade credit and Weibull distributed deterioration considered by[1] in a production inventory model under selling price depends demand. Trade credit and non-instantaneous deteriorated inventory model developed by[2] under two storage facility. Applying trade credit facility non-instantaneous deteriorated inventory system is developed by[3]. Non-instantaneous deterioration and trade credit investigates in an inventory problem by[4] considering probabilistic stock-price-advertisement dependent demand. Bi-level trade credit and non-instantaneous deterioration developed in an inventory model by[5] under preservation. A two-warehouse inventory problem is solved by[6] considering trade credit and deterioration. Three-level trade credit in supply chain problem is solved by[7] considering time-varying deterioration. An inventory problem considering non-instantaneous deterioration and trade credit is solved by[8] under stock dependent demand. Two-level trade credit and time dependent deterioration is considered in an inventory policy by[9] under variable demand. A promotional inventory system for price and sales efforts dependent demand is developed by[10]. Optimal pricing policy for a deteriorated inventory model for is developed by[11] with time and price depends demand under backlogging. Trade credit considered for a non-instantaneous deteriorating inventory model in[12]. Non-instantaneous deterioration effect on item is developed by[13] in an inventory system with selling price dependent demand during COVID-19 period. Permissible delay in payment considered in deteriorated inventory model in[14] where demand depends on time. In COVID-19 period work life balance and talent management is investigated in[15]. During COVID-19 period block chain framework investigated by[16].

Deterioration of items is common in any goods. For food item people are careful about the freshness. Weibull deterioration investigates in production inventory problem by[17]. Discrete-time perishable developed in an inventory model under time-varying demand by[18]. An inventory system for expiry items is investigated by[19] with trade credit using stock depending demand. Trade credit policy considered by[20] in an inventory system under replenishment. An inventory system developed by[21] considering delayed deterioration under two-storage facility and trade credit. A two warehouse inventory problem is solved by[22] assuming Weibull distributed deterioration and trade credit. Trade credit facility assuming inventory problem is solved by[23] under deterioration. An inventory problem considering non-instantaneous deterioration and constant demand is solved by[24] under trade credit.

Holding cost is crucial for profit earn. Organizations minimize holding cost for their business and sale their product with minimum selling price. Trade credit facility for two storage is considered in[25] under time-varying holding cost. Delayed deterioration is developed in an inventory system by[26] under trade credit with time varying holding cost. Variable holding cost considered in a two warehouse inventory model by[27] where demand depends on time and selling price. For municipality area economic rapid assessment is developed by[28].

This work considered the holding cost is constant for a period, then linearly time dependent. Trade credit period ends at the end of inventory cycle. Demand depends on stock as well as price of the item. Shortages are not allowed due low capital business as customers wait unbelievable. However, freshness of the item get prime important in this business. So, three-parameter Weibull distributed deterioration is considered. Discount on selling price allowed after starts of deterioration of the item to attract the customer. For the validation of the model two examples for different cycle length are solved by three types of quantum particle swarm optimization (QPSO). Then, a sensitivity analysis has been worked out and a fruitful conclusion is made.

Assumptions

Following assumptions are allowed to propose the inventory system

i) The inventory model considers infinite horizon and instantaneous replenishment.

ii) Demand is depending on stock level and selling price. Also, two selling price is considered. The form of demand is as

$$D(.) = \begin{cases} (a-bs)+wI(t), & t \le T_d \\ (a-bcs)+wI(t), & t > T_d \end{cases}$$

iii) Three parameter Weibull distributed deterioration is considered.

iv) Shortages are not allowed.

v) Trade credit applied and total purchase cost paid just end of business cycle. And delay-in- payment is negligible. No interest will be charged.

vi) Holding cost is time dependent and has two parts one is fixed for first four hours, another is linearly time dependent after four hours. And form of the holding cost is as

$$h = \begin{cases} h_1, & 0 \le t \le 4 \\ h_1 + h_2(t-4), & t > 4 \end{cases}$$

2 Methodology

Initially a retailer borrows Q unit of item at time $t = 0$ from a supplier in the morning of a day. As time goes, the stock level decreases for fulfilment of customers' demand upto time $t = T_d$. Then, deterioration occurs at time $t = T_d$ and level of inventory

Table 1. Notation

c_p	Purchase cost (in \$)/item
s	Selling price (in \$)/item
c	Discount or commission rate $0<c<1$
$D(.)$	Demand rate
h_1	Fixed holding cost (in \$) of an item per hour
h_2	Extra applied holding cost (in \$) after 4 hours of an item per hour
T_d	Deterioration start time (in hours)
T	Business cycle period (in hours)
w	Stock level controlling parameter
$\theta(t)$	At time t deterioration rate $\theta(t)=\alpha\beta(t-T_d)^{\beta-1}$
$I(t)$	At any time t inventory level
α	Deterioration shape parameter
β	Deterioration scale parameter
c_0	Replenishment cost (in \$) per replenishment
Q	Initial stock level
$AvP(s,T)$	Average profit function

decreases for effect of deterioration and fulfilment of customers' demand. After time T, stock level becomes to zero. Therefore, governing differential equation of the system is given by

$$\frac{dI(t)}{dt}=-(a-bs)-wI(t),\quad 0\leq t\leq T_d \tag{1}$$

$$\frac{dI(t)}{dt}+\theta(t)I(t)=-(a-bcs)-wI(t),\quad T_d<t\leq T \tag{2}$$

with boundary values $I(0)=Q$ and $I(T)=0$. And, at $t=T_d$, $I(t)$ is continuous.

By solving the differential equation, from (1) one can calculate by putting $I(0)=Q$

$$I(t)=Qe^{-wt}-\frac{(a-bs)}{w}\left(e^{-wt}-1\right) \tag{3}$$

and from (2) using $I(T)=0$

$$I(t)=(a-bcs)e^{-\left\{wt+\alpha(t-T_d)^{\beta}\right\}}\int_t^T e^{\left\{wu+\alpha(u-T_d)^{\beta}\right\}}du,\quad T_d<t\leq T \tag{4}$$

From equation (3) and (4) by continuity of

$Q=\frac{(a-bs)}{w}\left(e^{wT_d}-1\right)+(a-bcs)\int_{T_d}^T e^{\left\{wu+\alpha(u-T_d)^{\beta}\right\}}du$

Different inventory related costs are as follows:

Purchase cost (PC)=c_pQ

Holding cost (HC)

$$=h_1\left\{\frac{Q}{w}\left(1-e^{-wT_d}\right)+(a-bs)\frac{\left(1-wT_d-e^{-wT_d}\right)}{w^2}\right\}+h_1(a-bcs)\int_{T_d}^T e^{-\left\{wt+\alpha(t-T_d)^{\beta}\right\}}\times\int_t^T e^{\left\{wu+\alpha(u-T_d)^{\beta}\right\}}du\,dt+h_2(a-bcs)\int_4^T (t-4)e^{-\left\{wt+\alpha(t-T_d)^{\beta}\right\}}\int_t^T e^{\left\{wu+\alpha(u-T_d)^{\beta}\right\}}du\,dt$$

Replenishment cost (RC)=c_0

and Sales revenue (SR)= $= se^{-wT_d}(wQ+1)T_d + sw\left\{QT_d - (a-bs)\frac{T_d^2}{2}\right\} + cs(a-bcs)(T-T_d)$

$+csw(a-bcs)\int_{T_d}^{T} e^{-\left(wt+\alpha(t-T_d)^\beta\right)}\int_t^T e^{\left(wu+\alpha(u-T_d)^\beta\right)}dudt$

Thus, average profit function is

$$AvP(s,T) = \frac{1}{T}\left[se^{-wT_d}(wQ+1)T_d + sw\left\{\frac{Q}{2}(e^{-wT_d}+\ 1) + (a-bs)\frac{\left(e^{-wT_{d-1}}\right)}{2}\right\} + cs(a-bcs)\right.$$

$$\times(T-T_d) + csw(a-bcs)\int_{T_d}^{T} e^{-\left\{wt+\alpha(t-T_d)^\beta\right\}}\int_t^T e^{\left\{wu+\alpha(u-T_d)^\beta\right\}}du\,dt - c_pQ - h_1(a-bcs)$$

$$\times\int_{T_d}^{T} e^{-\left\{wt+\alpha(t-T_d)^\beta\right\}}\int_t^T e^{\left\{wu+\alpha(u-T_d)^\beta\right\}}du\,dt - h_1\left\{QT_d + \mathrm{csw}(a-bcs)int_{T_d}^{T}e^{-\left\{wt+\alpha(t-T_d)^\beta\right\}}\right.$$

$$\left.\times\int_t^T e^{\left\{wu+\alpha(u-T_d)^\beta\right\}}du - (a-bs)\frac{T_d^2}{2}\right\} - h_2(a-bcs)\int_4^T (t-4)e^{-\left\{wt+\alpha(t-T_d)^\beta\right\}}\times$$

$$\left.\int_t^T e^{\left\{wu+\alpha(u-T_d)^\beta\right\}}du\,dt - \mathrm{csw}(a-\ bcs)\int_{T_d}^{T} e^{-\left\{wt+\alpha(t-T_d)^\beta\right\}}\int_t^T e^{\left\{wu+\alpha(u-T_d)^\beta\right\}}du\,dt - c_0\right]$$

Hence, the optimization problem is

Maximize $AvP(s,T)$

subject to $0 \le T_d \le T$ and $a-bs > 0$.

Clearly, the objective function is highly non-linear and for solution soft computing needed. Here, Gaussian QPSO (GQPSO), Weighted QPSO (WQPSO) and Adaptive QPSO (AQPSO) techniques are used to solve. In GQPSO technique every solution can freely move in the search space near the previous solution.

Firstly, some feasible solutions $\left\{x_{ij} : 1 \le i \le n,\ 1 \le j \le m\right\}$ is considered which are initially best particles. Quantum behaviour of particle means a particle moves in an uncertain place under some bounded states. However, this idea comes under particle swam optimization by considering mean and standard deviation of its positions. This position is called central position p_{ij} of the related particle. Then, global best particle $X_{iG}, \forall i = 1,2,\cdots,n$ component wise can be found according to fitness among the particles by

$p_{ij} = \lambda x_{ij} + (1-\lambda)X_{iG},\ \ \forall i = 1,2,\cdots,n$ and λ is uniformly distributed number with mean zero and standard deviation one.

Then, updated particle can be determined by

$x_{ij}^{\text{New}} = p_{ij} \pm \beta\left|m_j - x_{ij}\right|\log\left(1/u_j\right), \forall i = 1,2,\cdots,n$ and $\forall j = 1,2,\cdots,m$

where β reduces from 0.5 to 1.0 and u_j is uniform distributed number with mean zero and standard deviation one. Also, the component wise mean m_j can be obtained for different techniques by

$m = \left(\frac{\sum_i p_{i1}}{mn}, \frac{\sum_i p_{i2}}{mn}, \cdots, \frac{\sum_i p_{in}}{mn}\right)$ for GQPSO technique, $m = \left(\frac{\sum_i \varepsilon_{i1}p_{i1}}{mn}, \frac{\sum_i \varepsilon_{i2}p_{i2}}{mn}, \cdots, \frac{\sum_i \varepsilon_{in}p_{in}}{mn}\right)$ for WQPSO technique and for AQPSO technique mean same as GQPSO with diversity bound. Here, ε_{ij} are weights of particle according to fitness. All the techniques are coded in C Programming language and more about the techniques, algorithms readers may follow[29,30].

3 Result and Discussion

To illustrated the proposed system two numerical examples are investigated on basis of collected data from retailer. The actual values for a retailer are fitted in this problem. The first example has no time bound for retailer and the second example is bound for four hour due to avoid excess pay of holding cost or other home works are assigned by the retailer.

Example 1: The inventory parameters for above then four hour work are as follows:

$c_p = \$8.0$, $h_1 = \$0.5$, $h_2 = \$0.3$, $c_0 = \$60.0$, $w = 0.5$, $a = 80.0$, $b = 1.6$, $T_d = 1.9$Hours, $\alpha = 1.3$, $\beta = 0.3$ and $c = 0.1$.

Example 2: The inventory parameters for only four hour of works are as follows:

$c_p = \$7.0$, $h_1 = \$0.5$, $h_2 = \$0.2$, $c_0 = \$50.0$, $w = 0.4$, $a = 90.0$, $b = 3.1$, $T_d = 2.0$ Hours, $\alpha = 1.2$, $\beta = 0.3$ and $c = 0.1$.

The optimization problems are solved by GQPSO, WQPSO and AQPSO techniques and the results are displayed in Table 1. Clearly, GQPSO technique gives the best result among them.

Sensitivity analyses are worked out for Example 1 with more than four hours of work. The sensitivity has performed by increasing a parameter from -20% to +20% and fixing other parameters originally by GQPSO technique. Graphical

Table 2. Obtained results for Example 1 and Example 2

Example	Technique	Average Profit (in $)	Selling Price (in $/unit)	Stock-in Period (in Hours)	Initial Stock
	GQPSO	**13357.432258**	**36.999955**	**10.99962**	**5163.450378**
Example 1	**WQPSO**	13357.276532	36.999738	10.999912	5163.407062
	AQPSO	13357.266678	36.999940	10.999829	5163.328161
	GQPSO	**899.126393**	**14.999728**	**3.99991**	**634.843755**
Example 2	**WQPSO**	899.103461	14.999988	3.999624	634.731682
	AQPSO	899.093924	14.999503	3.999894	634.836218

representations of sensitivities for different parameters are shown in Figures 1, 2, 3 and 4. Also, the figures are self-explanatory.

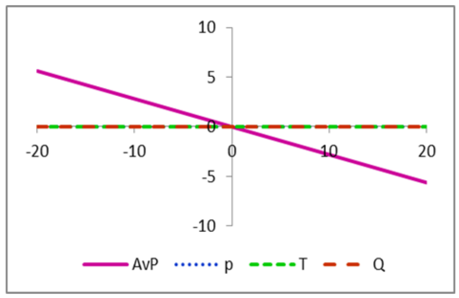

Fig 1. Optimal results by change of c_p

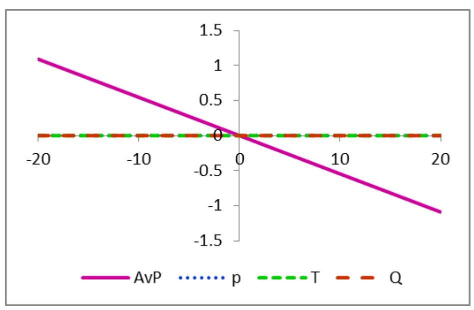

Fig 2. Optimality results by change of h_1

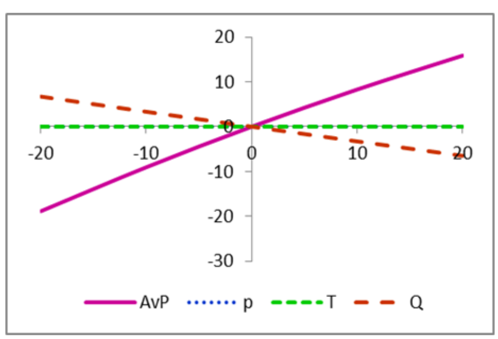

Fig 3. Optimality results by change of T_d

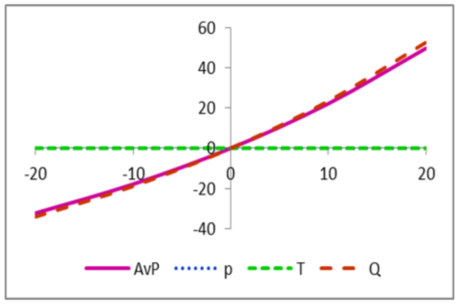

Fig 4. Optimality results by change of α

3.1 Managerial Insight

These two problems are gives very interesting results and are as follows:

i) Every retailer earns a suitable profit form business for work continuously about 11 hours of works. Supplier may replace the retailer according to his/her choice and rented house owner go for new deal in daily basis.

ii) There is no need of high capital to start this type of business as purchase cost paid on the day of business.

iii) A good understanding between retailer and supplier is needed.

iv) Retailer can work freely about their choice of work hour.

v) Also, as by locality man power can replenished by family members for very short period.

4 Conclusion

This inventory model deals with some real problems considering new type of time depending on holding cost. This model allowed trade credit period without interest charge. Holding cost has divided into two parts one fixed for a certain time period and then linear time dependent. Three-parameter Weibull distributed deterioration is considered and a discount on selling price allowed after deterioration starts in the item. Due to highly non-linear objective function, the problem is solved by QPSO techniques and then sensitivity analysis has performed.

This model could be extended by allowing partial trade credit, preservation, partial or fully backlogging. Also, the model can be extended in uncertainty by considering demand, different inventory related cost as interval valued.

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