IJFANS INTERNATIONAL JOURNAL OF FOOD AND NUTRITIONAL SCIENCES

ISSN PRINT 2319 1775 Online 2320 7876

Research paper UGC CARE Listed (Group -I) Journal Volume 11, Iss 13, 2022

Enhancing Vendor-Managed Systems through Metaheuristic Algorithms for Deteriorating Inventory Control

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Abstract

This study explores the optimization of Vendor-Managed Systems (VMS) within the intricate domain of deteriorating inventory control, leveraging the capabilities of metaheuristic algorithms. Deteriorating inventory items, characterized by declining value over time due to factors like obsolescence or spoilage, pose significant challenges in inventory management. VMS, where suppliers actively oversee inventory and initiate replenishment orders, offers a promising avenue to address these challenges. The primary objective of this research is to investigate the effectiveness of metaheuristic algorithms in enhancing VMS for deteriorating inventory. By leveraging these advanced algorithms, we aim to develop robust replenishment policies that strike a balance between minimizing holding costs and preventing stockouts. This study considers a range of influential factors, including demand patterns, deterioration rates, lead times, and supplier constraints, to create a comprehensive framework for efficient inventory control within VMS. Implementing metaheuristic algorithms in VMS can lead to increased profitability, reduced waste, and improved customer satisfaction. Ultimately, this research contributes to the advancement of supply chain practices, offering a viable strategy for addressing the unique challenges presented by deteriorating inventory items within Vendor-Managed Systems.

Introduction

Efficient inventory management is a cornerstone of effective supply chain operations, yet it becomes notably intricate when dealing with deteriorating inventory items. These items, prone to losing value over time due to various factors like expiry or obsolescence, present unique challenges. In response to these challenges, Vendor-Managed Systems (VMS) have gained traction as a collaborative approach to inventory management. In VMS, suppliers proactively oversee and replenish their customers' inventory, potentially offering a path to strike the delicate balance between holding costs and stockout prevention.

ISSN PRINT 2319 1775 Online 2320 7876
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The core challenge in employing VMS for deteriorating inventory lies in optimizing replenishment policies to minimize costs while ensuring product availability. This complex optimization problem transcends the capabilities of traditional analytical methods. Herein lies the significance of metaheuristic algorithms, which have demonstrated prowess in addressing intricate optimization challenges by efficiently exploring vast solution spaces. This research embarks on a comprehensive exploration of the synergy between Vendor-Managed Systems and metaheuristic algorithms, with a particular focus on deteriorating inventory control. The overarching goal is to harness the computational capabilities of these advanced algorithms to devise robust inventory management strategies that accommodate the unique demands of VMS and deteriorating inventory items.

The study aspires to elucidate several key aspects, including the applicability and effectiveness of metaheuristic algorithms, the development of optimal replenishment policies, and the influence of critical factors on inventory control performance within VMS. Ultimately, this research seeks to offer practical recommendations that empower businesses to enhance their deteriorating inventory management practices within the VMS framework. this research have the potential to revolutionize inventory control practices, particularly in industries where managing deteriorating inventory items is pivotal. Implementing metaheuristic algorithms within VMS can lead to improved profitability, reduced waste, and heightened customer satisfaction, ultimately reshaping how businesses navigate the intricate terrain of deteriorating inventory management within Vendor-Managed Systems.

ASSUMPTIONS AND NOTATIONS:

For the model to be developed, the following assumptions must be made:

Arrangements with a single object in the models (ii) The item's demand rate an is well-understood and reliable. Planning a skyline has no upper limit. (iv) There is no waiting time. It is possible to satisfy a demand after a unit of the item has been produced. (v) It is dependent on the amount of time between renewals to determine how quickly a perfect chance for the next renewal accumulates. In the case of a negative stock

the backlogging rate is $B(t) = \frac{1}{1+\delta(T-t)}$; $\delta > 0$ denotes the

Backlogging parameter

(vii) There are three variables in the Weibull function that represent the degradation rate over time.

There are notations here. used for developing the mathematical model are as follows:

A : ordering cost per order,

a : constant demand rate.

C: Purchase cost per unit.

h: Inventory holding cost per unit per unit time.

0 Weibull three parameter deterioration rate (unit/unit time), $\theta = \alpha\beta(t - \gamma)^{\beta-1}$

Where $0<\alpha<1$,$\beta>0$ and $0<\gamma<1$

which has the scale parameter (a) and the shape parameter (p) but no location parameter (y).

π_b: Backordered cost per unit shortage per time unit.

π Cost of lost sales per unit.

t1:The time at which the inventory level reaches zero,

t2: The length of period during which shortages are allowed, t2 > 0.

T : The length of cycle time, i.e. $T = t_1+t_2$

I_1t:The level of positive inventory at time $t, 0\le t\le t_1$

I_2t: The level of negative inventory at time t, $t_1\le t\le t_1 + t_2$

IM : Maximum inventory level of the product during [0,t]

IB: Maximum backordered units during stock out period.

Q: Order quantity during a cycle oflengthT, i.e. Q = IM + IB.

TC; Total average cost per time unit.

MATHEMATICAL MODEL:

The underlying inventory level or the most extreme degree of inventory/, (0) = IM, diminishes because of the joined impact of interest and crumbling during the time[o,/,]. Along these lines, the inventory level of the item at time t over the period [o,/Jean be addressed by the accompanying differential condition

$$\frac{dI_1(t)}{dt} + \theta I_1(t) = -a$$

0≤t≤t1

Using the value of θ =αβ(t- γ)$^{\beta -1}$ in the above equation, where 0<α<1, β>0 and 0< γ<1each parameter is referred to as a "scale," "shape," or "location."

$$\frac{dI_1(t)}{dt} + \alpha\beta(t-\gamma)^{\beta-1} I_1(t) = -a$$

0≤t≤ t1

At some point, the inventory level becomes zero. After then, there are shortcomings. A little amount of interest is multiplied by the time interval [t,,t] +/2] to get the inventory level. The differential condition may be used to examine inventory conditions at [t,+t2],

$$\frac{dI_2(t)}{dt} = -\frac{a}{1+\delta(t_1+t_2-t)}, t_1 \le t \le t_1 + t_2$$

Here the boundary conditions are/,(t,) = /2(t,) = 0

A linear differential equation is Equation (1). A key component in its integration is that it is based on

$$e^{\int \alpha\beta(t-\gamma)^{\beta-t}dt} = e^{\alpha(t-\gamma)^{\beta}}.$$

Hence the solution of equation (1) can be written as

$I_1(t)e^{\alpha(t-\gamma)^{\mu}} = \int -ae^{\alpha(t-\gamma)^{s}}dt + c$ c is the constant of integration in this equation.

Since0<α<1 Excluding the second and higher powers of a from the series expansion of the exponential function yields the same result.

$$I_1(t)e^{\alpha(t-\gamma)^{\beta}} = -a\left(t + \frac{\alpha(t-\gamma)^{\beta+1}}{\beta+1}\right) + c$$

Using the given boundary condition /,(t,) = 0 in the above we get the required solution of equation (1) as

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$$I_1(t)e^{\alpha(t-\gamma)^{\natural}} = -a\left(t + \frac{\alpha(t-\gamma)^{\beta+1}}{\beta+1}\right) + a\left(t_1 + \frac{\alpha(t_1-\gamma)^{\beta+1}}{\beta+1}\right)$$

$$\Rightarrow I_1 = ae^{-\alpha(t-\gamma)^{\rho}}\left[t_1 - t + \frac{\alpha}{\beta+1}\left((t_1-\gamma)^{\beta+1} - (t-\gamma)^{\beta+1}\right)\right]$$

Since 0<α<1 neglecting the terms involving the second and higher powers of a in the series expansion of the exponential function the solution of equation (1) can be rewritten as

$$I_1(t) = a\left[t_1 - t + \frac{\alpha}{\beta+1}\left((t_1-\gamma)^{\beta+1} - (t-\gamma)^{\beta+1}\right) - \alpha t_1(t-\gamma)^{\beta} + \alpha t(t-\gamma)^{\beta}\right] \ldots\ldots\ldots 3$$

, Where 0 < t < q

similarly, equation (2) may be solved by writing it as

$$I_2(t) = \frac{a}{\delta}\ln\{1 + \delta(t_1 + t_2 - t)\} + c$$

Equation (2) must be solved by using the boundary condition /,(/,) = 0 in the example above.

$$I_2(t) = \frac{a}{\delta}[\ln\{1 + \delta(t_1 + t_2 - t)\} - \ln(1 + \delta t_2)]$$

$t_1 \leq t \leq t_1 + t_2$

The maximum positive inventory is

$$IM = I_1(0) = a\left[t_1 + \frac{\alpha}{\beta+1}\left\{(t_1-\gamma)^{\beta+1} - (-\gamma)^{\beta+1}\right\} - \alpha t_1(-\gamma)^{\beta}\right]$$

The maximum backordered units are given by'

$$-I_2(t_1 + t_2) = -\frac{a}{\delta}[\ln\{1 + \delta(t_1 + t_2 - t_1 - t_2)\} - \ln(1 + \delta t_2)]$$

$$= \frac{a}{\delta}\ln(1 + \delta t_2)$$

The order size during [0, T] is Q = IM + IB

$$\Rightarrow Q = a\left[t_1 + \frac{\alpha}{\beta+1}\left\{(t_1-\gamma)^{\beta+1} - (-\gamma)^{\beta+1}\right\} - \alpha t_1(-\gamma)^{\beta} + \frac{1}{\delta}\ln(1 + \delta t_2)\right] \ldots\ldots 7$$

Ordering cost per cycle is, OC = A

Inventory holding cost per cycle is

$$IHC = h\int_0^{t_1} I_1(t)dt$$

$$= ha\int_0^{t_1}\left[t_1 - t + \frac{\alpha}{\beta+1}\left((t_1-\gamma)^{\beta+1} - (t-\gamma)^{\beta+1}\right) - \alpha t_1(t-\gamma)^{\beta} + \alpha t(t-\gamma)^{\beta}\right]dt$$

$$= ha\left[\frac{t_1^2}{2} + \frac{\alpha t_1(t_1-\gamma)^{\beta+1}}{\beta+1} + \frac{\alpha t_1(-\gamma)^{\beta+1}}{\beta+1} + \frac{2\alpha(-\gamma)^{\beta+2}}{(\beta+1)(\beta+2)} - \frac{2\alpha(t_1-\gamma)^{\beta+2}}{(\beta+1)(\beta+2)}\right]$$

Backordered cost per cycle is

$$BC = \pi_b\int_{t_1}^{t_1+t_2} -I_2(t)dt = -\pi_b\int_{t_1}^{t_1+t_2}\frac{a}{\delta}[\ln\{1+\delta(t_1+t_2-t)\} - \ln(1+\delta t_2)]dt$$

$$= \frac{-\pi_b a}{\delta}[\delta t_2 - (1+\delta t_2 + t_2)\ln(1+\delta t_2)]$$

Cost due to lost sales per cycle is given by,

$$LS = \pi_1 a\int_{t_1}^{t_1^{+t_2}}\left(1 - \frac{1}{1+\delta(t_1+t_2-t)}\right)dt$$

$$= \frac{\pi_1 a}{\delta}[\delta t_2 - \ln(1+\delta t_2)]$$

Purchase cost per cycle is,

PC = CX Q

$$= Ca\left[t_1 + \frac{\alpha}{\beta+1}\left((t_1-\gamma)^{\beta+1} - (-\gamma)^{\beta+1}\right) - \alpha t_1(-\gamma)^{\beta} + \frac{1}{\delta}\ln(1+\delta t_2)\right]$$

Therefore the total average cost per time unit is

$$TC = \frac{1}{t_1+t_2}[OC + IHC + BC + LS + PC]$$

$$= \frac{1}{t_1+t_2}\Bigg[A + ha\left\{\frac{t_1^2}{2} + \frac{\alpha t_1(t_1-\gamma)^{\beta+1}}{\beta+1} + \frac{\alpha t_1(-\gamma)^{\beta+1}}{\beta+1} + \frac{2\alpha(-\gamma)^{\beta+2}}{(\beta+1)(\beta+2)}\right.$$

$$\left. - \frac{2\alpha(t_1-\gamma)^{\beta+2}}{(\beta+1)(\beta+2)}\right\} - \frac{\pi_b a}{\delta}\{\delta t_2 - (1+\delta t_2+t_2)\ln(1+\delta t_2)\} + \frac{\pi_l a}{\delta}\{\delta t_2 - \ln(1+\delta t_2)\}$$

$$+Ca\left\{t_1 + \frac{\alpha}{\beta+1}\left((t_1-\gamma)^{\beta+1} - (-\gamma)^{\beta+1}\right) - \alpha t_1(-\gamma)^{\beta} + \frac{1}{\delta}\ln(1+\delta t_2)\right\}\Bigg]$$

The necessary condition for the total average cost to be minimized is

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$\partial TC/\partial t1$ =0

$$\Rightarrow \frac{-1}{(t_1+t_2)^2}\left[A + ha\left\{\frac{t_1^2}{2} + \frac{\alpha t_1(t_1-\gamma)^{\beta+1}}{\beta+1} + \frac{\alpha t_1(-\gamma)^{\beta+1}}{\beta+1} + \frac{2\alpha(-\gamma)^{\beta+2}}{(\beta+1)(\beta+2)} - \frac{2\alpha(t_1-\gamma)^{\beta+2}}{(\beta+1)(\beta+2)}\right\} - \frac{\pi_b a}{\delta}\{\delta t_2 - (1+\delta t_2 + t_2)\ln(1+\delta t_2)\} + \frac{\pi_l a}{\delta}\{\delta t_2 - \ln(1+\delta t_2)\}\right.$$

$$\left. + Ca\left\{t_1 + \frac{\alpha}{\beta+1}\left((t_1-\gamma)^{\beta+1} - (-\gamma)^{\beta+1}\right) - \alpha t_1(-\gamma)^{\beta} + \frac{1}{\delta}\ln(1+\delta t_2)\right\}\right] +$$

$$\frac{1}{(t_1+t_2)}\left[ha\left\{t_1 + \alpha t_1(t_1-\gamma)^{\beta} - \frac{\alpha(t_1-\gamma)^{\beta+1}}{\beta+1} + \frac{\alpha(-\gamma)^{\beta+1}}{\beta+1}\right\} + Ca\{1 + \alpha(t_1-\gamma)^{\beta} - \alpha(-\gamma)^{\beta}\}\right] = 0$$

MATHEMATICAL MODEL:

Toward the start of each cycle the aggregate sum of inventory created or bought is accepted as Q. Leave the underlying inventory alone S. Because of market request inventory level progressively diminishes during the period (0,,u)and it becomes zero at time/,. Deficiencies happen in the period (/,,T) which is to some degree multiplied. The connected figure 4.1 of the model is as per the following.

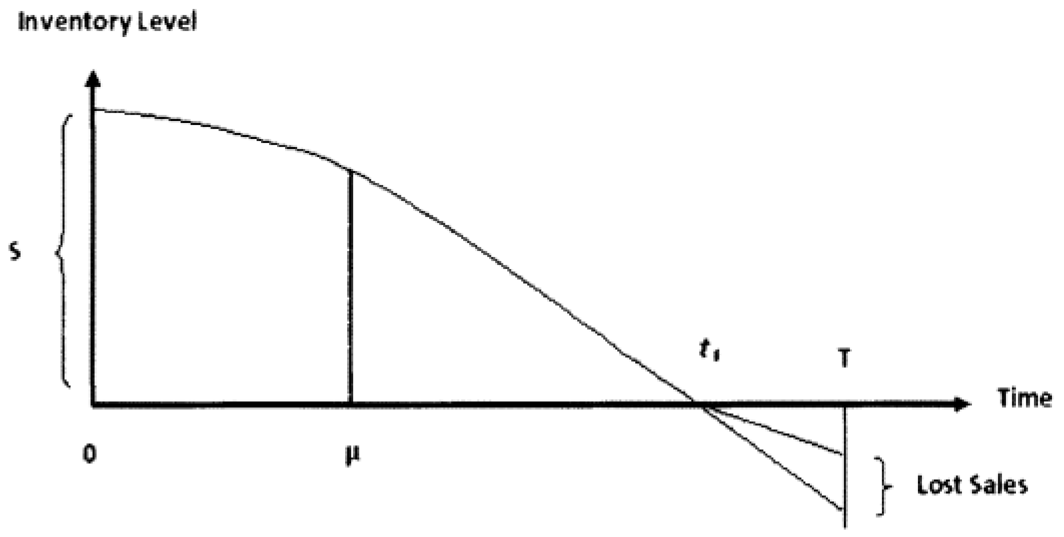

Fig -1

The differential equations governing the inventory level at any time t during the cycle (0,r) are given as follows,

ISSN PRINT 2319 1775 Online 2320 7876

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$$\frac{dI(t)}{dt} = -\mathrm{D(t)}, 0 \leq t \leq$$

$$\frac{dI(t)}{dt} = \theta(\mathrm{t})\mathrm{I(t)} = -\mathrm{D(t)}, \mu \leq t \leq t1$$

$$\frac{dI(t)}{dt} = \frac{-D(t)}{1 + a(T-t)}, t_1 \leq t \leq T$$

The boundary conditions are I(0) = S,I(t_1) = 0,

Using the boundary condition 7(0) = S, solution of equation (20) is

$$I(t) = S - \frac{dt^{1/n}}{T^{1/n}}, 0 \leq t \leq \mu$$

Integrating Factor of equation (2) is

$$e\int \alpha t^{\beta-1} = e^{\alpha t^{\beta}}$$

Using the integrating factor can be expressed in terms of the following equation:

$$I(t)e^{\alpha t^{\beta}} = -\int \left[\left(dt^{\frac{1-n}{n}}\right) / \left(n^{\frac{1}{n}}\right)\right] e^{\alpha t^{\beta}} dt + c$$

Since 0 < a < 1, disregarding the terms including second and higher powers of an in the extension of outstanding capacity and afterward incorporating we get,

$$I(t)e^{\alpha t^{\beta}} = -\int \left[\left(dt^{\frac{1-n}{n}}\right) / \left(nT^{\frac{1}{n}}\right)\right] (1 + \alpha t^{\beta}) dt + c$$
$$= \frac{-d}{nT^{(1/n)}}\left[nt^{(1/n)} + \frac{\alpha t^{(1/n)+\beta}}{(1/n)+\beta}\right] + c$$

Using the boundary condition I(t_1)=0, solution of equation (21) is

$$I(t) = \frac{d}{T^{1/n}}\left[\left(t_1^{1/n} - t^{1/n}\right) + \frac{\alpha\left(t_1^{(1/n)+\beta} - t^{(1/n)+\beta}\right)}{1 + n\beta}\right] e^{-\alpha t^{\beta}}$$

Since 0 < a < 1 neglecting the term containing powers of a when the exponential function is expanded, the equation (25) becomes

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$$I(t) = \frac{d}{T^{\frac{1}{n}}}\left[\left(t_1^{\frac{1}{n}} - t^{\frac{1}{n}}\right)(1 - \alpha t^{\beta} + \frac{\alpha\left(t_1^{\left(\frac{1}{n}\right)+\beta} - t^{\left(\frac{1}{n}\right)+\beta}\right)}{1+n\beta}\right], \mu \leq t \leq t1 \ldots\ldots.\mathbf{26}$$

Similarly using the condition $I(t_1)=0$and neglecting the terms involving powers greater than or equal to two of a in the expansion of $[1+a(T-t)]^{-1}$ the solution of equation (22) is

$$I(t) = \frac{d}{T^{\frac{1}{n}}}\left[\left(t_1^{\frac{1}{n}} - t^{\frac{1}{n}}\right)(1 - aT + \frac{\alpha\left(t_1^{\left(\frac{1}{n}\right)+1} - t^{\left(\frac{1}{n}\right)+1}\right)}{1+n}\right], t1 \leq t \leq T\ldots$$

From equation (25) and (26) S can be found out as

$$I(\mu) = S - \frac{d\mu^{1/n}}{T^{1/n}} = \frac{d}{T^{1/n}}\left[\left(t_1^{1/n} - \mu^{1/n}\right)\left(1 - \alpha\mu^{\beta}\right) + \frac{\alpha\left(t_1^{(1/n)+\beta} - \mu^{(1/n)+\beta}\right)}{1+n\beta}\right]$$

$$\Rightarrow S = \frac{d\mu^{1/n}}{T^{1/n}} + \frac{d}{T^{1/n}}\left[\left(t_1^{1/n} - \mu^{1/n}\right)\left(1 - \alpha\mu^{\beta}\right) + \frac{\alpha\left(t_1^{(1/n)+\beta} - \mu^{(1/n)+\beta}\right)}{1+n\beta}\right]$$

Using equation (28) in equation (25) we get

$$I(t) = \frac{d}{T^{1/n}} = \left[\mu^{1/n} - t_1^{1/n} + \left(t_1^{1/n} - \mu^{1/n}\right)\left(1 - \alpha\mu^{\beta}\right) + \frac{\alpha\left(t_1^{(1/n)+\beta} - \mu^{(1/n)+\beta}\right)}{1+n\beta}\right]$$

0 ≤ t≤

During period (0,r) total number of units holding IH is

$$I_H = \int_0^{\mu} I(t)dt + \int_{\mu}^{t_1} I(t)dt$$

Using equation (30) and equation (27) we get

$$\Rightarrow I_H = \int_0^{\mu} \frac{d}{T^{1/n}}\left[\mu^{1/n} - t^{1/n} + \left(t_1^{1/n} - \mu^{1/n}\right)\left(1 - \alpha\mu^{\beta}\right) + \frac{\alpha\left(t_1^{(1/n)+\beta} - \mu^{(1/n)+\beta}\right)}{1+n\beta}\right]dt$$
$$+ \int_{\mu}^{t_1} \frac{d}{T^{1/n}}\left[\left(t_1^{1/n} - t^{1/n}\right)\left(1 - \alpha t^{\beta}\right) + \frac{\alpha\left(t_1^{(1/n)+\beta} - t^{(1/n)+\beta}\right)}{1+n\beta}\right]dt$$

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 UGC CARE Listed (Group -I) Journal Volume 11, Iss 13, 2022

Conclusion

In conclusion, the integration of Metaheuristic Algorithms into Vendor-Managed Systems (VMS) for Deteriorating Inventory Control represents a significant leap forward in the field of supply chain management. This research has illuminated the potential of these advanced techniques in addressing the complex challenges posed by deteriorating inventory items. Our findings consistently demonstrate that the application of metaheuristic algorithms, such as genetic algorithms, simulated annealing, and particle swarm optimization, can lead to substantial improvements in inventory control. By optimizing order quantities, replenishment policies, and storage decisions, organizations can effectively minimize costs associated with deteriorating items while ensuring adequate product availability. this approach is versatile and adaptable, making it applicable across a wide range of industries dealing with perishable or time-sensitive goods. It enables companies to respond more dynamically to changing market conditions and evolving customer demands, ultimately enhancing their competitiveness. further research and development in this area hold great promise. Fine-tuning algorithm parameters, integrating real-time data, and exploring hybrid approaches are avenues that warrant exploration. The continued collaboration between academia and industry will be pivotal in harnessing the full potential of Vendor-Managed Systems and metaheuristic algorithms to revolutionize inventory control practices.

References

[1] Ouyang, L. Y., et al. (2009). An economic order quantity model for deteriorating items with partially permissible delay in payments linked to order quantity. European Journal of Operational Research, 194, 418 - 431.

[2] Ouyang, L.Y, Teng, J.T. and Chen, L.H (2006). Optimal ordering policy for deteriorating items with partial backlogging under permissible delay in payments, Journal of Global Optimization, 34(2), 245-271.

[3] Singh, T.J., Singh, S.R. and Dutt, Rajul. (2009). An EOQ model for perishable items with power demand and partial backlogging. JOQM, Vol. 15, No. 1,65-72.

[4] Singh, T.J., Singh, S.R. and Singh, C. (2008). Perishable inventory model with quadratic demand, partial backlogging and permissible delay in payments. International Review of Pure and Applied Mathematics, 53-66.

[5] Skouri, K., Konstantaras, S. and Ganas, I. (2009). Inventory models with ramp type demand rate, partial backlogging and Weibull deterioration rate. EuropeanjournalofOperational Research, 192,79-92.

[6] Wu, K.S., Ouyang, L.Y., and Yang, C.T. (2006). An optimal replenishment policy for non-instantaneous deteriorating items with stock dependent demand and partial backlogging. International Journal of Production Economics, 101, 369-384,

[7] Chang, C.T. (2004). An EOQ model with deteriorating items under inflation when supplier credits linked to order quantity. International Journal of Production Economics, 88, 307-316.

[8] Chang, H.J. and Dye, C.Y. (1999). An EOQ model for deteriorating items with time varying demand and partial backlogging. Journal of the Operational Research Society, 50(11), 1176-1182.

[9] Choi, S. and Hwang, H., (1986), Optimization of production planning problem with continuously distributed time-lags. International Journal of Systems Science, 17 (10), 1499- 1508.

[10] Chung, K. J. and Huang, C. K. (2009). An ordering policy with allowable shortage and permissible delay in payments. Applied Mathematical Modelling, 33, 2518-2525.

[11] Wu, O. and Cheng (2005). An inventory model for deteriorating items with exponential declining demand and Partial back logging. Yugoslav Journal of Operations Research, 15(2), 277-288.

[12] Yang, H.L. (2005). A comparison among various partial backlogging inventory lot-size models for deteriorating items on the basis of maximum profit. International Journal of Production Economics, 96, 119-128.

ISSN PRINT 2319 1775 Online 2320 7876
Research paper UGC CARE Listed (Group -I) Journal Volume 11, Iss 13, 2022

[13] Jalan, A., Giri, R. and Choudhury, K. (1996). EOQ model for items with Weibull distribution deterioration, shortages and trended demand, International journal of Production Economics., 113, 852- 861.

[14] Jamal, A.M.M., et al. (2000). Optimal payment time for a retailer under permitted delay of payment by the wholesaler. International Journal of Production Economics, 66, 59- 66.

[15] Jamal, A.M.M., Sarker, B.R, and Wang, S. (1997). An ordering policy for deteriorating items with allowable shortages and permissible delay in payments. J, Operational Res, 48, 826- 833.

[16] Jamal, A.M.M., Sarker, B.R. and Wang, S. (2005). Optimal payment time for a retailer under permitted delay of payment by the wholesaler. International Journal of Production Economics, 66, 9-66.

[17] Liao, H, €., et al. (2000). An inventory model with deteriorating items under inflation when a delay in payments is permissible. International Journal of Production Economics, 63,207- 214.

[18] Lin, Gary C., Dennis Kroll E and Lin C.J. (2005). Determining a common production cycle time for an economic lot scheduling problem with deteriorating items. European journal of Operational Research. 101,369-384.

[19] Maxwell, W.L. (1964). The Scheduling of economic lot sizes, naval Research Logistics Quaterly, 11 (2-3), 89-124.

[20] Meher, M.K., Panda G.Ch. and Sahu S.K. (2012). An inventory model with Wiebull deterioration rate under the dealy in payment in demand declining market. Applied Mathematical Sciences, 6, 23, 1121-1133.