Auto Industry inventory model for deteriorating items with two warehouse and Transportation Cost using Simulated Annealing Algorithms

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Abstract

A deterministic inventory model of Auto industry article deterioration using Simulated Annealing Algorithms has been developed. He advocates a type of ramp with inflation effects in dual storage facilities of Auto industry. The own warehouse of Auto industry has a fixed capacity of W. units. The rented warehouse (RW) of Auto industry has unlimited capacity. We have assumed here that storage costs of Auto industry in RW were higher than in OW using Simulated Annealing Algorithms. Inventory of Auto industry bottlenecks are allowed and partially deferred using Simulated Annealing Algorithms assumes that inventory of Auto industry will deteriorate over time with a variable rate of deterioration of Auto industry using Simulated Annealing Algorithms. The inflation effect has also been taken into account for various costs associated with the inventory system of Auto industry and the using Simulated Annealing Algorithms. The numerical example is also used to examine the behaviour of the model. The cost minimization technique is used to obtain the terms of total cost and other parameters.

Keywords:- *Two-warehouses, deterministic inventory, Transportation Cost, Advertising Cost and Simulated Anneali*

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1. Introduction

Basically, the inventory management and control system responds to the problems of demand and the supply chain of Auto industry. The business is entirely based on the demand and supply of goods, whether they are finished products or raw materials of Auto industry. In order to meet the demand of the consumer or supplier, it is necessary to interrogate the articles at all times and, for the same purpose, sufficient space is required to store the goods in order to meet the requirements of Auto industry. The room in which the goods are stored is called a warehouse of Auto industry. Traditional models assume that demand and ownership costs are constant and goods are delivered on demand, but over time many researchers believe that demand may vary with price and time of Auto industry. Other factors and holding costs may also vary over time and depending on other factors. Many models have been developed taking into account different time-dependent demands, with deficit and without defect of Auto industry. For all of these models, which take into account the variability of demand in response to inventories, it is assumed that the costs of ownership are constant throughout the inventory cycle of Auto industry. Review of bearing models often assumes unlimited storage capacity. However, in very busy markets such as supermarkets, supermarket markets, etc., storage space for items may be limited of Auto industry. Another case of insufficient storage space can occur when it is decided to purchase a large number of items. This may be because an attractive discount is available for bulk purchases or when the cost of purchasing goods is greater than other inventory costs, or when the demand for items is very high or if Article considered is

An article deals with a seasonal product such as the yield of a crop or when problems arise with frequent supply of Auto industry. In this case, these items can not be housed in your existing warehouse of Auto industry. To store surplus items, an additional warehouse has been installed, possibly located near its own warehouse of Auto industry. First, it was 1 who discussed a rolling model with two storage systems of Auto industry. In order to reduce storage costs, it is necessary to consume RW's assets at the earliest due to the higher holding costs of Auto industry.

Simulated Annealing (SA) is a technique for finding good solution to minimization problems. It simulates the physical annealing process of solidifying a metal to a uniform crystalline structure. In order to achieve this uniform crystalline structure the metal is first heated to a molten state and the gradually cooled down. The critical parameter of this process is the rate of cooling. If the cooling takes place too quickly energy gaps will be formed resulting in non-uniformity in the crystalline structure. On the other hand if the cooling takes place too slowly then time is wasted. The optimal cooling rate varies from metal to metal.

2. Literature Review

Yadav and Swami (2018) analyzed a integrated supply chain model for deteriorating items with linear stock dependent demand under imprecise and inflationary environment. Yadav and Swami (2018) discuss a partial backlogging production-inventory lot-size model with time-varying holding cost and weibull deterioration. Yadav, et., al. (2018) presented a supply chain inventory model for decaying items with two ware-house and partial ordering under inflation. Yadav, et., al. (2018) proposed an inventory model for deteriorating items with two warehouses and variable holding cost. Yadav, et., al. (2018) analyzed a inventory of electronic components model for deteriorating items with warehousing using genetic algorithm. Yadav, et., al. (2018) discuss a analysis of green supply chain inventory management for warehouse with environmental collaboration and sustainability performance using genetic algorithm. 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(2016) presented a multi objective optimization for electronic component inventory model & deteriorating items with two-warehouse using genetic algorithm. Yadav (2017) analyzed a modeling and analysis of supply chain inventory model with two-warehouses and economic load dispatch problem using genetic algorithm. Yadav, et., al. 2018 discuss a particle swarm optimization for inventory of auto industry model for two warehouses with deteriorating items. Yadav, et., al. (2018) analyzed a hybrid techniques of genetic algorithm for inventory of auto industry model for deteriorating items with two warehouses. Yadav, et., al. (2018) discuss a supply chain management of pharmaceutical for deteriorating items using genetic algorithm. Yadav, et., al. (2018) analyzed a particle swarm optimization of inventory model with two-warehouses. Yadav, et., al. (2018) presented a supply chain management of chemical industry for deteriorating items with warehouse using genetic algorithm. Yadav (2017) discuss a analysis of seven stages supply chain management in electronic component inventory optimization for warehouse with economic load dispatch using ga and PSO. Yadav, et., al. (2017) gives a multi-objective genetic algorithm optimization in inventory model for deteriorating items with shortages using supply chain management. Yadav, et., al. (2017) analyzed a supply chain management in inventory optimization for deteriorating items with genetic algorithm. Yadav, et., al. (2017) discuss a modeling & analysis of supply chain management in inventory optimization for deteriorating items with genetic algorithm and particle swarm optimization. Yadav, et., al. (2017) presented a multi-objective particle swarm optimization and genetic algorithm in inventory model for deteriorating items with shortages using supply chain management. Yadav, et., al. (2017) proposed soft computing optimization of two warehouse inventory model with genetic algorithm. Yadav, et., al. 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3. Assumption and notations

The mathematical model of two warehouse inventory model for deteriorating items is based on the following notation and assumptions

Notations:

O_c: Cost of ordering per Order of Auto industry

φ: Capacity of OW of Auto industry.

T : The length of replenishment cycle of Auto industry.

M: Maximum inventory level per cycle to be ordered of Auto industry.

t_1: the time up to which product has no deterioration of Auto industry.

t_2: The time at which inventory level reaches to zero in RW of Auto industry.

t_3: The time at which inventory level reaches to zero in OW of Auto industry.

H^{OW}: The holding cost per unit time in OW of Auto industry i.e. $H^{OW}=(ab+1)_1t$;where $(ab+1)_1$ is positive constant.

H^{RW}: The holding cost per unit time in RW of Auto industry i.e. $H^{RW}=(ab+1)_2t$where $(ab+1)_2>0$ and $H^{RW}>H^{OW}$.

S_c: The shortages cost per unit per unit time of Auto industry.

$I^{1RW}(t)$: The level of inventory in RW at time $[0\ \ t_1]$ in which the product has no deterioration of Auto industry.

$I^{2RW}(t)$: The level of inventory in RW at time $[t_1\ \ t_2]$in which the product has deterioration of Auto industry.

$I^{1OW}(t)$: The level of inventory in OW at time $[0\ \ t_1]$ in which the product has no Deterioration of Auto industry.

$I^{2OW}(t)$: The level of inventory in OW at time $[t_1\ t_2]$ in which only Deterioration takes place of Auto industry.

$I^{3OW}(t)$: The level of inventory in OW at time $[t_2\ t_3]$ in which Deterioration takes place of Auto industry.

Is(t): Determine the inventory level at time t in which the product has shortages of Auto industry.

$(\gamma + \sigma + \phi)$: Deterioration rate in RW of Auto industry Such that $0<(\gamma+\sigma+\phi)<1$;

$(\Phi + \sigma)$: Deterioration rate in OW of Auto industry such that $0<(\Phi+\sigma)<1$;

R_d: Deterioration cost per unit in RW of Auto industry.

O_d: Deterioration cost per unit in OW of Auto industry.

T_C: Cost of transportation per unit per cycle of Auto industry

r : (Discount rate – inflation i.e., r=d-i)

$T^{IC}(t_2, t_3, T)$: The total relevant inventory cost per unit time of inventory system of Auto industry.

Assumption

1. Replenishment rate is infinite and lead time is negligible i.e. zero.
2. Holding cost is variable and is linear function of time of Auto industry.
3. The time horizon of the inventory system is infinite of Auto industry.
4. Goods of OW are consumed only after the consumption of goods kept in RW due to the more holding cost in RW than in OW of Auto industry.
5. The OW has the limited capacity of storage and RW has unlimited capacity of Auto industry.
6. Demand vary with time and is linear function of time and given by $D(t)=(\Psi\eta+\theta)t$; where $(\Psi\eta+\theta)>0$;
7. For deteriorating items a fraction of on hand inventory deteriorates per unit time in both the warehouse with different rate of Deterioration of Auto industry.
8. Shortages are allowed and demand is fully backlogged at the beginning of next replenishment of Auto industry.
9. The unit inventory cost (Holding cost of Auto industry + Deterioration cost of Auto industry) in RW>OW.

4. Mathematical formulation of model and analysis

In the beginning of the cycle at t=0 a lot size of M units of inventory of Auto industry enters into the system in which backlogged (M-R) units are cleared and the remaining units R is kept into two storage of Auto industry as W units in OW and RW units in RW.

$$\frac{dI^{1RW}(t)}{dt} = -(\Psi\eta+\theta)\,t \quad ; \quad 0\le t\le t_1 \quad (1)$$

$$\frac{dI^{2RW}(t)}{dt} = -(\gamma+\sigma+\phi)\,I^{2RW}(t) - (\Psi\eta+\theta)t \quad ; \quad t_1\le t\le t_2 \quad (2)$$

$$\frac{dI^{1W}(t)}{dt} = 0 \; ; \quad 0\le t\le t_1 \quad (3)$$

$$\frac{dI^{2W}(t)}{dt} = -(\Phi+\sigma)\,I^{2W}(t) \; ; \quad t_1\le t\le t_2 \quad (4)$$

$$\frac{dI^{3W}(t)}{dt} = -(\Phi+\sigma)\,I^{3W}(t) - (\Psi\eta+\theta)t \; ; \quad t_2\le t\le t_3 \quad (5)$$

$$\frac{dI^{4S}(t)}{dt} = -(\Psi\eta+\theta)t \; ; \quad t_3\le t\le T \quad (6)$$

Now inventory level at different time intervals is given by solving the above differential equations (1) to (6) with boundary conditions as follows:

At t=0, $I^{1RW}(t)=R-W$; therefore Differential eq. (1) gives

$$I^{1RW}(t)=R-W-\frac{(\Psi\eta+u)t^2}{2} \quad ; \quad 0\le t\le t_1 \quad (7)$$

Differential eq. (2) is solved at $t=t_2$ and boundary condition $I^{2RW}(t_2)=0$, which yields

$I^{2RW}(t)=\frac{(\Psi\eta+u)}{\alpha^2}\{((\gamma+\sigma+\phi)t_2-1)e^{(\gamma+\sigma+\phi)(t_2-t)}-((\gamma+\sigma+\phi)t-1)\}$; $t_1\leq t\leq t_2$ (8)

Solution of differential eq. (3) with boundary condition at t=0 and $I^{1OW}(0)=W$

$I^{1OW}(t)=\varphi$; $0\leq t\leq t_1$ (9)

Differential eq. (4) yields at $t=t_1$ and $I^{2OW}(t_1)=\varphi$

$I^{2OW}(t)=\varphi e^{(\Phi+\sigma)(t_1-t)}$ $t_1\leq t\leq t_2$ (10)

Solution of eq. (5) at $t=t_3$ and $I^{3OW}(t_3)=0$ gives

$I^{3OW}(t)=\frac{(\Psi\eta+\theta)}{(\Phi+\sigma)^2}\{(\Phi t_3-1)e^{(\Phi+\sigma)(t_3-t)}-((\Phi+\sigma)t-1)\}$; $t_2\leq t\leq t_3$ (11)

Lastly the solution of eq. (6) at $t=t_3$ and $I^{4S}(t_3)=0$, is given as

$I^{4S}(t)=\frac{(\Psi\eta+\theta)}{2}\{t_3^2-t^2\}$; $t_3\leq t\leq T$ (12)

Now considering the continuity of $I^{1R}(t_1)=I^{2R}(t_1)$, at $t=t_1$ from eq. (7) & (8) we have

$R=\varphi+\frac{(\Psi\eta+\theta)t_1^2}{2}+\frac{(\Psi\eta+\theta)}{\alpha^2}\{((\gamma+\sigma+\phi)t_2-1)e^{(\gamma+\sigma+\phi)(t_2-t_1)}-((\gamma+\sigma+\phi)t_1-1)\}$; (13)

Substituting eq.(13) into eq. (7) we have

$I^{1RW}(t)=\frac{b}{2}(t_1^2-t^2)+\frac{b}{\alpha^2}\{((\gamma+\sigma+\phi)t_2-1)e^{(\gamma+\sigma+\phi)(t_2-t_1)}-((\gamma+\sigma+\phi)t_1-1)\}$; (14)

Cost of inventory shortages during time interval $[t_3\ T]$ is given by

$IS=\int_{t_3}^{T}[-I_s(t)]dt$

$=-\frac{(a\eta+\theta)}{2}\int_{t_3}^{T}(t_3^2-t^2)dt$

$=\frac{b}{6}\{T^3+2t_3^3-3t_3^2T\}$ $t_3\leq t\leq T$ (15)

The maximum Inventory to be ordered is

$M=R+IS$

$=\varphi+\frac{bt_1^2}{2}+\frac{b}{\alpha^2}\{((\gamma+\sigma+\phi)t_2-1)e^{(\gamma+\sigma+\phi)(t_2-t_1)}-((\gamma+\sigma+\phi)t_1-1)\}+\frac{b}{6}\{T^3-2t_3^3-3t_3^2T\}$;

(16)

Next the total relevant inventory cost per cycle consists of the following elements:

(I). Ordering Cost

$O_c=\rho_0$ (17)

(II). Transportation Cost

$T_C=\rho_1+1$

(III). Advertising Cost

$A_C=\rho_2+1$

(IV). Inventory holding cost in RW denoted by I^{HR} and is given as

$I^{HRW}=\int_0^{t_1} I^{1RW}(t)(ab+1)_2 tdt + \int_{t_1}^{t_2} I^{2RW}(t)(ab+1)_2 tdt\ ]$

$= \frac{bb_2}{8} t_1^4 + \frac{(\Psi\eta+\theta)(ab+1)_2}{2(\gamma+\sigma+\phi)^2}\{((\gamma+\sigma+\phi)t_2-1)e^{(\gamma+\sigma+\phi)(t_2-t_1)} - ((\gamma+\sigma+\phi)t_1-1)\}\ \}t_1^2 + \frac{(\Psi\eta+\theta)(ab+1)_2}{(\gamma+\sigma+\phi)^4}(\gamma t_2 - 1)\{(e^{\gamma(t_2-t_1)}-1) - (\gamma+\sigma+\phi)(t_2 - t_1 e^{\gamma(t_2-t_1)})\} - \frac{(\Psi\eta+\theta)(ab+1)_2}{6(\gamma+\sigma+\phi)^2}\{2(\gamma+\sigma+\phi)(t_2^3 - t_1^3) - 3(t_2^2 - t_1^2)\}$ (18)

(V). Inventory holding cost in OW denoted by I^{HOW} and is given by

$I^{HOW}=\int_0^{t_1} I^{1OW}(t)(ab+1)_1 t\,dt + \int_{t_1}^{t_2} I^{2OW}(t)dt + \int_{t_2}^{t_3} I^{3OW}(t)(ab+1)_1 tdt$

$= \frac{\varphi(ab+1)_1 t_1^2}{2} + \frac{(ab+1)_1\varphi}{(\Phi+\sigma)^2}\{(1-e^{-(\Phi+\sigma)(t_2-t_1)}) - (\Phi+\sigma)(t_2 e^{-(\Phi+\sigma)(t_2-t_1)} - t_1)\}$

$+\frac{bb_1}{\Phi^4}((\Phi+\sigma)t_3 - 1)\{(e^{(\Phi+\sigma)(t_3-t_2)}-1) - (\Phi+\sigma)(t_3 - t_2 e^{(\Phi+\sigma)(t_3-t_2)})\}$

$-\frac{(\Psi\eta+\theta)(ab+1)_1}{6\Phi^2}\{2(\Phi+\sigma)(t_3^3 - t_2^3) - 3(t_3^2 - t_2^2)\}$ (19)

(VI). Cost of inventory deteriorated in RW is denoted and given by

$I^{DRW}=(R-W) - \int_{t_1}^{t_2}(a\eta+\theta)t\,dt$

$= \frac{b}{\alpha^2}\{((\gamma+\sigma+\phi)t_2 - 1)e^{(\gamma+\sigma+\phi)(t_2-t_1)} - ((\gamma+\sigma+\phi)t_1 - 1)\} - \frac{(ab+1)}{2}(t_2^2 - 2t_1^2)$

(VII). Cost of deteriorated inventory in RW is given by

$CI^{DRW} = D_R\ \{\frac{b}{\alpha^2}\{((\gamma+\sigma+\phi)t_2 - 1)e^{(\gamma+\sigma+\phi)(t_2-t_1)} - ((\gamma+\sigma+\phi)t_1 - 1)\} - \frac{(\Psi\eta+\theta)}{2}(t_2^2 - 2t_1^2)\ \}$ (20)

(VIII). Cost of inventory deteriorated in OW is denoted and given by

$I^{DOW}=\varphi - \int_{t_2}^{t_3}(\Psi\eta+\theta)t\,dt$

$=\varphi - \frac{b}{2}(t_3^2 - t_2^2)$

(IX). Cost of deteriorated inventory in OW is given by

$CI^{DOW}=O_d\ \{\varphi - \frac{(\Psi\eta+\theta)}{2}(t_3^2 - t_2^2)\}$ (21)

(X). Shortages Cost

$CIS=S_c[\ \frac{(\Psi\eta+\theta)}{6}\{T^3 + 2t_3^3 - 3t_3^2 T\}]$ (22)

T^{IC} (t_2, t_3 T) $=\frac{1}{T}$ [Ordering cost + Transportation Cost **+** Advertising Cost + Inventory holding cost per cycle in RW + Inventory holding cost per cycle in OW +Deterioration cost per cycle in RW+ Deterioration cost per cycle in OW + Shortage cost]

$T^{IC}(t_2, t_3, T) = \frac{1}{T}[O_c + T_C + A_C + I^{HRW} + I^{HOW} + CI^{DRW} + CI^{DOW} + CIS]$ (23)

Substituting equations (17) to (22) in equation (23) we get

$$\mathbf{T^{IC}(t_2,\ t_3,\ T)}=\frac{1}{T}[(\rho_0+(\rho_1+1)+(\rho_2+1)+\frac{bb_2}{8}t_1^4+\frac{(\Psi\eta+\theta)(ab+1)_2}{2(\gamma+\sigma+\phi)^2}\{((\gamma+\sigma+\phi)t_2-1)e^{(\gamma+\sigma+\phi)(t_2-t_1)}-\ ((\gamma+\sigma+\phi)t_1-1)\}t_1^2+\frac{(\Psi\eta+\theta)(ab+1)_2}{(\gamma+\sigma+\phi)^4}(\alpha t_2-1)\{\left(e^{\alpha(t_2-t_1)}-1\right)-(\gamma+\sigma+\phi)(t_2-t_1e^{\alpha(t_2-t_1)})\}-\frac{(\Psi\eta+\theta)(ab+1)_2}{6(\gamma+\sigma+\phi)^2}\{2(\gamma+\sigma+\phi)(t_2^3\text{-}t_1^3)\text{-}3(t_2^2\text{-}t_1^2)\}+\frac{\varphi(ab+1)_1t_1^2}{2}+\frac{(ab+1)_1\varphi}{\beta^2}\{(1-e^{-(\Phi+\sigma)(t_2-t_1)})-(\Phi+\sigma)(t_2e^{-(\Phi+\sigma)(t_2-t_1)}-t_1)\}+\frac{bb_1}{\Phi^4}((\Phi+\sigma)t_3-1)\{(e^{(\Phi+\sigma)(t_3-t_2)}-1)-(\Phi+\sigma)(t_3-t_2e^{(\Phi+\sigma)(t_3-t_2)})\}-\frac{(ab+1)(a+b+1)_1}{6\Phi^2}\{2(\Phi+\sigma)(t_3^3\text{-}t_2^3)\text{-}3(t_3^2\text{-}t_2^2)\}+R_d\{\frac{b}{\alpha^2}\{((\gamma+\sigma+\phi)t_2-1)e^{(\gamma+\sigma+\phi)(t_2-t_1)}-\left((\gamma+\sigma+\phi)t_1-1\right)\}+\frac{(\Psi b+1)}{2}(t_2^2-t_1^2)\}+O_d\{\varphi-\frac{b}{2}(t_3^2-t_2^2)\}+S_c\{\frac{b}{6}\{T^3+2t_3^3-3t_3^2T\}\} \quad (24)$$

The total relevant inventory cost is minimum if

$$\frac{\partial T^{IC}}{\partial t_2}=0\ \ ;\ \ \frac{\partial T^{IC}}{\partial t_3}=0\ \ ;\ \ \frac{\partial T^{IC}}{\partial T}=0 \quad (25)$$

6. Numerical Example:

In order to illustrate the above solution procedure, consider an inventory system with the following data in appropriate units: ρ_0=31, (ρ_2+1)= 230, (ρ_2+1)= 450, φ =380, (Ψη+θ)=23, $(ab+1)_1$=6.1, $(ab+1)_2$=7.1, t_1=2.3, (γ+σ+ϕ)=4.25, (Φ+σ)=6.52, C_s=3.3, and C_t=9.1 The vales of decision variables are competed for the model and also for the models of special cases.

Simulated Annealing
population=81, generations=520, initial cooling temperature =234 and cooling constant=1.27.

7. Conclusion

In this article, we proposed a deterministic inventory model of Auto industry with two stocks of Auto industry for non-immediate deterioration of constant demand items of Auto industry using Simulated Annealing Algorithms. It is assumed that articles are shipped from RW of Auto industry to retail stores in a streaming pattern to minimize the total costing function of the stock model using Simulated Annealing Algorithms. We find that all relevant storage costs are affected by the selling price and the interest rate earned of Auto industry. All relevant inventory costs will be minimized if the time allowed is longer than the order cycle or if the retailer pays their total purchase cost at the end of the specified period of Auto industry using Simulated Annealing Algorithms. In addition, the proposed model can be used to control stocks of certain trade-damaged items and can be expanded by incorporating a time-dependent requirement, a likely demand model, variable holding costs, and so on of Auto industry using Simulated Annealing Algorithms.

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