Hazardous Substance Storage Inventory Model for decaying Items using Differential Evolution

Ajay Singh Yadav[1]
Department of Mathematics
SRM Institute of Science and Technology, Delhi-NCR Campus Ghaziabad, Uttar Pradesh, India

Navyata[2]
Research Scholar
Mewar University, Chittorgarh, Rajasthan.

Navin Ahlawat[3]
Department of Computer Science
SRM Institute of Science and Technology, Delhi-NCR Campus Ghaziabad, Uttar Pradesh, India

Tripti Pandey[4]
Department of Computer Science & Engineering
SRM Institute of Science and Technology, Delhi-NCR Campus Ghaziabad, Uttar Pradesh, India

Abstract

Hazardous Substance Storage inventory model is developed for decaying items with ramp type demand and the effects of inflation using Differential Evolution. The Hazardous Substance Storage has unlimited capacity. Here, we assumed that the inventory holding cost in Hazardous Substance Storage is higher. Shortages in inventory are allowed and partially backlogged and it is assumed that the inventory deteriorates over time at a variable deterioration rate. Cost minimization technique is used to get the expressions for total cost using Differential Evolution and numerical example is also used to study the behavior of the model.

Keywords: - *Inventory model, Deterioration rate, Ramp type demand, Inflation, DE algorithm & Probabilistic tools.*

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1. Introduction

In the current market, the explosion of choice due to fierce competition means that no company can resist inventory because there are a variety of alternative products with additional features. In addition, there is no dry cut recipe, with which the need can be determined exactly. Therefore, when an enterprise requires an inventory, it must be preserved so that the physical attributes of inventory elements can be preserved and protected. How an organization stores its stocks depends critically on its ability to achieve the ultimate goal of inventory management. An organization collects the same stocks in different ways to achieve different results, even generating profits and losses. Materials storage ultimately turns out to be the core of the overall inventory management practice. Hazardous Substance storage containers are stores for the storage and storage of goods and the provision of other related services to encourage distributors and / or manufacturers to maintain products in a scientific and systematic manner, in order to that they regain their original value, quality and utility preserve. It is an integral part of an industrial unit. It acts as the custodian of all materials required by the industrial unit and supplier materials as needed. Sometimes the total requirement for an item is such that the supplier is more likely to buy than he can store it in his Hazardous Substance store. You could have been influenced by the offer of a reduced price for the stock if you bought at least a certain amount. Or you can expect a season of strong sales and you want to be prepared in advance so you do not lose the chance to make big profits. Another may be an impending strike, subcontracting or lockout that may threaten a recovery period. He may want to prepare for this period by buying more than he can actually store in his own Hazardous Substance store. In busy markets such as supermarkets, community markets, etc., storage space for items is limited. If an attractive discount is available for bulk purchases, or if the purchase cost of the goods is greater than other costs related to inventory or demand for very large items or if there are problems with frequent purchases, management decides to buy a lot of items. Save time. These items cannot be stored in the existing warehouse in the booming market. In this case, an additional storage of Hazardous Substances is rented on a rental basis for the storage of surplus items.

The storage of Hazardous Substances is the storage of controlled Hazardous Substances or hazardous substances in Hazardous Substance storage facilities, Hazardous Substance storage cabinets or similar equipment. Improper storage of Hazardous Substances can compromise workplace safety, including heat, fire, explosions and leaking toxic gases. Hazardous Substance storage cabinets are typically used to safely store small amounts of Hazardous Substances at a workplace or laboratory for regular use. These cabinets are usually made of Hazardous Substancely resistant materials that are stored in them and sometimes contain a packed tray to recover spilled material. Hazardous Substance stores are warehouses commonly used by Hazardous Substance or pharmaceutical companies for the storage of bulk Hazardous Substances. In the United States, the storage and handling of potentially hazardous products must be disclosed to occupants in accordance with the applicable Occupational Safety and Health Administration (OSHA) legislation. Hazardous Substance storage devices are typically found in workplaces that require the use of non-hazardous and / or hazardous Substances. Proper storage is essential for the safety and access of laboratory technicians.

2. Differential Evolution

DE uses the randomly sampled difference in object vector pairs to control the mutation process, making it relatively new compared to other algorithms. Similar to GA, a randomly generated population is created. For each person, three more people are randomly selected. A new vector is created by adding a weighted difference (mutation factor) from two individuals to another. Crossbreeding or recombination is one of the main operators of AG, but complementary in DE. When all people are treated in this way, the physical form is evaluated. If the physical value of the new individual is better than that of the old, replace the old with the new one. This process is repeated until the maximum number of generations or convergence is reached.

3. 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. Yadav and kumar (2017) presented a electronic components supply chain management for warehouse with environmental collaboration & neural networks. Yadav, et., al. (2017) analyzed a effect of inflation on a two-warehouse inventory model for deteriorating items with time varying demand and shortages. Yadav, et., al. (2017) discuss an inflationary inventory model for deteriorating items under two storage systems. Yadav, et., al. (2017) proposed a fuzzy based two-warehouse inventory model for non instantaneous deteriorating items with conditionally permissible delay in payment. Yadav (2017) analyzed a analysis of supply chain management in inventory optimization for warehouse with logistics using genetic algorithm. Yadav, et., al. (2017) discuss a supply chain inventory model for two warehouses with soft computing optimization. Yadav, et., al. (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 Hazardous Substance industry for deteriorating items with warehouse using genetic algorithm. 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4. Assumptions and Notations

In developing the mathematical model of the inventory system the following assumptions are being made:

1. A single item is considered over a prescribed period T units of time.
2. The demand rate D(t) at time t is deterministic and taken as a ramp type function of time i.e. $D(t) = u_0 e^{-(\lambda_0+1)\{t-(t-t_1)H(t-t_1)\}}, u_0 > 0, (\lambda_0+1) > 0$
3. The replenishment rate is infinite and lead-time is zero.
4. When the demand for goods is more than the supply. Shortages will occur. Customers encountering shortages will either wait for the vender to reorder (backlogging cost involved) or go to other vendors (lost sales cost involved). In this model shortages are allowed and the backlogging rate is exp [-(δ_0+1)t], when inventory is in shortage. The backlogging parameter (δ_0+1) is a positive constant.
5. The variable rate of deterioration in Hazardous Substance Storage is taken as $(\theta+1)$(t) = $(\theta+1)$t.
6. No replacement or repair of deteriorated items is made during a given cycle.
7. The Hazardous Substance Storage has unlimited capacity.

In addition, the following notations are used throughout this paper:

I_{HSS}(t)	The inventory level in Hazardous Substance Storage at any time t.
T	Planning horizon.
(r_0+1)	Inflation rate.
A_{HC}	The holding cost per unit per unit time in Hazardous Substance Storage.
A_{DC}	The deterioration cost per unit.
A_{SC}	The shortage cost per unit per unit time.
A_{LS}	The opportunity cost due to lost sales.
A_{OC}	The replenishment cost per order.
$HSSTC(t_1,T)$	Hazardous Substance Storage Total Cost

5. Formulation and Solution of The Model

The inventory level at Hazardous Substance Storage is governed by the following differential equations:

$$\frac{dI_{HSS}(t)}{dt}+(\theta+1)(t)I_{HSS}(t)=-u_0e^{-(\lambda_0+1)t}, \qquad 0\le t<t_1 \qquad (1)$$

With the boundary condition t_1 (0) = 0, the solution of the equation (1) is

$$I_{CS}(t)=u_0\left\{(t_1-t)-\frac{(\lambda_0+1)}{2}\left(t_1^2-t^2\right)+\frac{(\theta+1)}{6}(t_2^3-t^3)\right\}e^{-(\theta+1)t^2/2}, \qquad t_1\le t\le t_2 \qquad (2)$$

The total average cost consists of following elements:

1. Ordering cost per cycle in Hazardous Substance Storage

$$CS_{OC}=A_{OC} \qquad (3)$$

2. Holding cost per cycle in Hazardous Substance Storage

$$CS_{HC}=A_{HC}\left[\int_0^{t_1} I_{HSS}(t)e^{-(r_0+1)t}dt\right] \qquad (4)$$

3. Cost of deteriorated units per cycle in Hazardous Substance Storage

$$HSS_{DC}=A_{DC}\left[\int_0^{t_1}(\theta+1)tI_0(t)e^{-(r_0+1)t}dt+\int_{\mu}^{t_2}(\theta+1)tI_0(t)e^{-(r_0+1)(t+t_1)}dt\right] \qquad (5)$$

4. Shortage cost per cycle in Hazardous Substance Storage

$$HSS_{SC}=A_{SC}\left[\int_{t_2}^{T}-I_{HSS}(t)e^{-(r_0+1)(t_2+t)}dt\right] \qquad (6)$$

5. Opportunity cost due to lost sales per cycle in Hazardous Substance Storage

$$HSS_{LS}=A_{LS}\int_{t_2}^{T}u_0(1-e^{-(\delta_0+1)t})e^{-(\lambda_0+1)t_1}e^{-(r_0+1)(t_2+t)}dt \qquad (7)$$

Therefore, the total average cost per unit time of our model is obtained as follows

$$HSSTC(t_1,T)=\frac{1}{T}\left[HSS_{OC}+HSS_{HC}+HSS_{DC}+HSS_{SC}+HSS_{LS}\right] \qquad (8)$$

To minimize the total cost per unit time, the optimal values of t_1 and T can be obtained by solving the following equations simultaneously

Therefore, numerical solution of these equations is obtained by using the software **MATLAB 7.0.1**.

6. Continuous Random Variable and Probability Density Function

Continuous Random Variable

Definition:- A random variable X with F_X (.) as Continuous Random Variable is called Continuous if there exists a function f_X (.): $R\to[0,\infty)$ Such that

$$F_X(x)=\int_{-\infty}^{x}f_X(t)\,dt \text{ for all } x\in R$$

The function $f_X(.)$ is called the Probability density function of X

Probability Density Function

Definition:- Any function $f_X(.)$: $R \to [0,\infty)$ is said to be a **Probability Density Function if**

$(i) f(x) \geq 0$ for all $x \in R$

$$\int_{-\infty}^{\infty} f(x)\,dx = 1$$

Theorem:-If X is a continuous random variable with Probability Density Function $f_X(x)$ Show that

$$E(X) = \int_0^{\infty}\left[1 - F_X(x)\right]dx - \int_{-\infty}^{0} F_X(x)\,dx$$

Proof:- By definition we have

$$E(X) = \int_{-\infty}^{\infty} x f_X(x)\,dx$$

$$E(X) = \int_0^{\infty} x f_X(x)\,dx + \int_{-\infty}^{0} x f_X(x)\,dx \qquad (12)$$

$$E(X) = \int_0^{\infty}\left[1 - F_X(x)\right]dx - \int_{-\infty}^{0} F_X(x)\,dx$$

$$F_X(x) = P(X \leq x)$$
and
$$1 - F_X(x) = P(X > x)$$

$$\int_0^{\infty}\left[1 - F_X(x)\right]dx = \int_0^{\infty} P(X > x)\,dx$$

$$\int_0^{\infty}\left[1 - F_X(x)\right]dx = \int_0^{\infty}\left[\int_x^{\infty}\left[f_X(y)\right]dy\right]dx$$

$$\int_0^{\infty}\left[1 - F_X(x)\right]dx = \int_0^{\infty}\left[f_X(y)\right]\left[\int_0^{y} dx\right]dy$$

By change of order of integration in the region A

$$\int_0^{\infty}\left[1 - F_X(x)\right]dx = \int_0^{\infty} y f_X(y)\,dy$$

$$\int_0^{\infty}\left[1 - F_X(x)\right]dx = \int_0^{\infty} x f_X(x)\,dx \qquad (13)$$

Consider

$$\int_{-\infty}^{0}\left[F_X(x)\right]dx = \int_{-\infty}^{0} P(X \leq x)\,dx$$

$$\int_{-\infty}^{0}\left[F_X(x)\right]dx = \int_{-\infty}^{0}\left[\int_{-\infty}^{x} f_X(y)\,dy\right]dx$$

$$\int_{-\infty}^{0}\left[F_X(x)\right]dx=\int_{-\infty}^{0} f_X(y)\left[\int_{y}^{0}dx\right]dy$$

By change of order of integration in the region B

$$\int_{-\infty}^{0}\left[F_X(x)\right]dx=-\int_{-\infty}^{0} yf_X(y)\,dy$$

$$\int_{-\infty}^{0}\left[F_X(x)\right]dx=-\int_{-\infty}^{0} xf_X(x)\,dx$$

$$-\int_{-\infty}^{0}\left[F_X(x)\right]dx=\int_{-\infty}^{0} xf_X(x)\,dx \quad (14)$$

From (12), (13), (14); we obtain

$$E(X)=\int_{0}^{\infty}\left[1-F_X(x)\right]dx-\int_{-\infty}^{0} F_X(x)\,dx$$

Theorem:-If X is a continuous random variable with Probability Density Function $f_X(x)$ Show that

$$\text{var}[X]=\int_{0}^{\infty}2x\left[1-F_X(x)+F_X(-x)\right]dx-\mu_X^2$$

Solution:- By definition

$$v\text{ar}[X]=E\left[X^2\right]-\left\{E[X]^2\right\}$$

$$v\text{ar}[X]=E\left[X^2\right]-\mu_X^2 \quad (15)$$

$$E\left[X^2\right]=\int_{-\infty}^{\infty}x^2 f_x(x)dx \quad (16)$$

$$\int_{0}^{\infty}2x\left[1-F_X(x)\right]dx=\int_{0}^{\infty}2xP(X>x)\,dx$$

$$\int_{0}^{\infty}2x\left[1-F_X(x)\right]dx=\int_{0}^{\infty}2x\left[\int_{x}^{\infty}\left[f_X(y)\right]dy\right]dx$$

$$\int_{0}^{\infty}2x\left[1-F_X(x)\right]dx=\int_{0}^{\infty}\left[f_X(y)\right]\left[\int_{0}^{y}2xdx\right]dy$$

By change of order of integration

$$\int_{0}^{\infty}2x\left[1-F_X(x)\right]dx=\int_{0}^{\infty}y^2 f_X(y)dy \quad (17)$$

Similarly

$$\int_{0}^{\infty}2x\left[1-F_X(x)\right]dx=\int_{0}^{\infty}x^2 f_X(x)dx$$

$$\int_{0}^{\infty}2x\left[F_X(-x)\right]dx=\int_{0}^{\infty}2x\left[\int_{-\infty}^{-x}\left[f_X(y)\right]dy\right]dx$$

$$\int_{0}^{\infty}2x\left[F_X(-x)\right]dx=\int_{-\infty}^{0}\left[f_X(y)\right]\left[\int_{0}^{-y}2xdx\right]dy$$

By change of order of integration

$$\int_0^\infty 2x\left[F_X(-x)\right]dx = \int_{-\infty}^{0} y^2 f_X(y)dy$$

$$\int_0^\infty 2x\left[1-F_X(x)\right]dx = \int_{-\infty}^{0} x^2 f_X(x)dx \qquad (18)$$

From (17) and (18) we get

$$\int_0^\infty 2x\left[1-F_X(x)\right]dx + \int_0^\infty 2x\left[F_X(-x)\right]dx = \int_0^\infty x^2 f_X(x)dx + \int_{-\infty}^{0} x^2 f_X(x)dx$$

$$\int_0^\infty 2x\left\{\left[1-F_X(x)\right]+\left[F_X(-x)\right]\right\}dx = \int_{-\infty}^{\infty} x^2 f_X(x)dx$$

$$\int_0^\infty 2x\left\{\left[1-F_X(x)\right]+\left[F_X(-x)\right]\right\}dx = E\left[X^2\right]$$

Putting in (15) we get

$$\operatorname{var}[X] = \int_0^\infty 2x\left[1-F_X(x)+F_X(-x)\right]dx - \mu_X^2$$

6. Numerical Illustration

To illustrate the model numerically the following parameter values are considered.

u_0 = 100 units, A_{OC} = Rs. 200 per order, r_0 = 1.05 unit, λ_0 = 0.4 unit, A_{HC} = Rs. 20.0 per unit, θ =0.004 unit, t_1 = 0.4 year, A_{LS} = Rs. 8.0 per unit, δ_0 = 0.2 unit, T = 1 year,

Then for the minimization of total average cost and with help of software. the optimal policy can be obtained such as:

t_2 = 1.993344 year, S = 76.9877225 units and C.S.T.C. = Rs.316.22608 per year.

Comparison of the optimization methods DE to enhance Hazardous Substance Storage Inventory in presence of FACTS device is presented in this section. The control parameter values for all the optimization algorithms are given below

• DE: population=60, generations=600, differentiation factor randomly between=-3.0 to 3.0, crossover probability=1.90

Table:- Differential Evolution (DE) model optimal solution

P	WW	DE			
	OPT	BEST	MAX	AVG	STD
1	651.10	671.10	672.10	662.10	652.10
2	651.11	671.11	672.11	662.11	652.11
3	651.21	672.21	673.21	663.21	653.21
4	651.23	672.23	673.23	663.23	653.23
5	651.24	672.24	673.24	663.24	653.24
6	651.54	673.54	674.54	664.54	654.54
7	651.58	673.58	674.58	664.58	654.58

7. Conclusion

This study incorporates some realistic features that are likely to be associated with the Hazardous Substance Storage inventory of any material using Differential Evolution. Decay (deterioration) overtime for any material product and occurrence of shortages in inventory are natural phenomenon in real situations using Differential Evolution. Hazardous Substance Storage Inventory shortages are allowed in the model using Differential Evolution. In many cases customers are conditioned to a shipping delay, and may be willing to wait for a short time in order to get their first choice using Differential Evolution. Generally speaking, the length of the waiting time for the next replenishment is the main factor for deciding whether the backlogging will be accepted or not using Differential Evolution. The willingness of a customer to wait for backlogging during a shortage period declines with the length of the waiting time using Differential Evolution. Thus, Hazardous Substance Storage inventory shortages are allowed and partially backordered in the present chapter and the backlogging rate is considered as a decreasing function of the waiting time for the next replenishment using Differential Evolution. Demand rate is taken as exponential ramp type function of time, in which demand decreases exponentially for the some initial period and becomes steady later on using Differential Evolution. Since most decision makers think that the inflation does not have significant influence on the inventory policy, the effects of inflation are not considered in some inventory models. However, from a financial point of view, an inventory represents a capital investment and must complete with other assets for a firm's limited capital funds using Differential Evolution. Thus, it is necessary to consider the effects of inflation on the inventory system. Therefore, this concept is also taken in this model. From the numerical illustration of the model, it is observed that the period in which inventory holds increases with the increment in backlogging and ramp parameters while inventory period decreases with the increment in deterioration and inflation parameters. Initial inventory level decreases with the increment in deterioration, inflation and ramp parameters while inventory level increases with the increment in backlogging parameter using Differential Evolution. The total average cost of the system goes on increasing with the increment in the backlogging and deterioration parameters while it decreases with the increment in inflation and ramp parameters. The proposed model can be further extended in several ways. For example, we could extend this deterministic model in to stochastic model. Also, we could extend the model to incorporate some more realistic features, such as quantity discount or the unit purchase cost, the inventory holding cost and others can also taken fluctuating with time using Differential Evolution.

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