# Probabilistic inventory model based Hazardous Substance Storage for decaying Items and Inflation using Particle Swarm Optimization

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 Particle Swarm Optimization. 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 Particle Swarm Optimization and numerical example is also used to study the behavior of the model.*

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

---

## 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. Particle Swarm Optimization

The PSO algorithm is based on the social behavior of birds. This algorithm first creates a random population. Each individual called particle is given a speed and a small social network. For all particles, the values of the fitness or objective function are evaluated. On the basis of physical condition in relation to GA, the PSO has no cross / mutation, but the personal optimum for each individual, the overall optimum in the total population and the neighborhood optimum found by the neighbors of each individual are stored for speed and position update each. This process is repeated until the maximum 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. 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. (2017) analyzed a multi-objective genetic algorithm involving green supply chain management. Yadav, et., al. (2017) presented a multi-objective particle swarm optimization algorithm involving green supply chain inventory management. Yadav, et., al. (2017) gives a green supply chain management for warehouse with particle swarm optimization algorithm. Yadav, et., al. (2017) analyzed a analysis of seven stages supply chain management in electronic component inventory optimization for warehouse with economic load dispatch using genetic algorithm. Yadav, et., al. (2017) discuss a analysis of six stages supply chain management in inventory optimization for warehouse with artificial bee colony algorithm using genetic algorithm. Yadav, et., al. (2016) presented a analysis of electronic component inventory optimization in six stages supply chain management for warehouse with abc using genetic algorithm and PSO. Yadav, et., al. (2016) analyzed a two-warehouse inventory model for deteriorating items with variable holding cost, time-dependent demand and shortages. Yadav, et., al. (2016) discuss a two warehouse inventory model with ramp type demand and partial backordering for weibull distribution deterioration. Yadav, et., al. (2016) proposed a two-storage model for deteriorating items with holding cost under inflation and genetic algorithms. Singh, et., al. (2016) analyzed a two-warehouse model for deteriorating items with holding cost under particle swarm optimization. Singh, et., al. (2016) presented a two-warehouse model for deteriorating items with holding cost under inflation and soft computing techniques. Sharma, et., al. (2016) gives an optimal ordering policy for non-instantaneous deteriorating items with conditionally permissible delay in payment under two storage management. Yadav, et., al. (2016) discuss a analysis of genetic algorithm and particle swarm optimization for warehouse with supply chain management in inventory control. Swami, et., al. (2015) analyzed an inventory policies for deteriorating item with stock dependent demand and variable holding costs under permissible delay in payment. Swami, et., al. (2015) presented an inventory model for decaying items with multivariate demand and variable holding cost under the facility of trade-credit. Swami, et., al. (2015) discuss an inventory model with price sensitive demand, variable holding cost and trade-credit under inflation. Gupta, et., al. (2015) proposed a binary multi-objective genetic algorithm &PSO involving supply chain inventory optimization with shortages, inflation. Yadav, et., al. (2015) analyzed a soft computing optimization based two ware-house inventory model for deteriorating items with shortages using genetic algorithm. Gupta, et., al. (2015) discuss a fuzzy-genetic algorithm based inventory model for shortages and inflation under hybrid & PSO. Yadav, et., al. (2015) presented a two warehouse inventory model for deteriorating items with shortages under genetic algorithm and PSO. taygi, et., al. (2015) analyzed an inventory model with partial backordering, weibull distribution deterioration under two level of storage. Yadav and Swami (2014) presented a two-warehouse inventory model for deteriorating items with ramp-type demand rate and inflation. Yadav and Swami (2013) discuss a effect of permissible delay on two-warehouse inventory model for deteriorating items with shortages. Yadav and Swami (2013) analyzed a two-warehouse inventory model for decaying items with exponential demand and variable holding cost. Yadav and Swami (2013) presented a partial backlogging two-warehouse inventory models for decaying items with inflation.

## 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 [$-(\delta_0+1)$t], when inventory is in shortage. The backlogging parameter $(\delta_0+1)$ 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:

$$\frac{dI_{HSS}(t)}{dt} + (\theta+1)(t) I_{HSS}(t) = -u_0 e^{-(\lambda_0+1)t}, \qquad 0 \le t < t_1 \qquad (1)$$

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**

$$HSS_{DC} = A_{DC}\left[\int_0^{t_1} (\theta+1) t I_0(t) e^{-(r_0+1)t} dt + \int_{\mu}^{t_2} (\theta+1) t I_0(t) e^{-(r_0+1)(t+t_1)} dt\right] \qquad (5)$$

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*

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

Proof:- By definition we have

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

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

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

$$F_X(x) = P(X \leq x)$$

*and*

$$1 - F_X(x) = P(X > x)$$

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

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

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

By change of order of integration in the region A

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

$$\int_{0}^{\infty}\left[1-F_X(x)\right]dx=\int_{0}^{\infty}xf_X(x)dx \tag{13}$$

Consider

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

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

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

By change of order of integration in the region B

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

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

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

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*

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

Solution:- By definition

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

$$v\operatorname{ar}[X]=E\left[X^2\right]-\mu_X^2 \tag{15}$$

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

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

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

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

By change of order of integration

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

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

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

## 7. 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, $\lambda_0$ = 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, $\delta_0$ = 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 PSO 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

• PSO: population=60, generations=600, cognitive learning factor=4, cooperative factor=4, social learning factor=1.0, inertial constant=1.0 and number of neighbors=10.

**Table:- Particle Swarm Optimization (PSO) model optimal solution**

| P | WW | PSO | | | |
|---|---|---|---|---|---|
| | OPT | BEST | MAX | AVG | STD |
| 1 | 251.10 | 271.10 | 272.10 | 262.10 | 252.10 |
| 2 | 251.11 | 271.11 | 272.11 | 262.11 | 252.11 |

| | | | | | |
|---|---|---|---|---|---|
| 3 | 251.21 | 272.21 | 273.21 | 263.21 | 253.21 |
| 4 | 251.23 | 272.23 | 273.23 | 263.23 | 253.23 |
| 5 | 251.24 | 272.24 | 273.24 | 263.24 | 253.24 |
| 6 | 251.54 | 273.54 | 274.54 | 264.54 | 254.54 |
| 7 | 251.58 | 273.58 | 274.58 | 264.58 | 254.58 |

## 8. Conclusion

This study incorporates some realistic features that are likely to be associated with the Hazardous Substance Storage inventory of any material using Particle Swarm Optimization.. Decay (deterioration) overtime for any material product and occurrence of shortages in inventory are natural phenomenon in real situations using Particle Swarm Optimization.. Hazardous Substance Storage Inventory shortages are allowed in the model using Particle Swarm Optimization.. 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 Particle Swarm Optimization. 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 Particle Swarm Optimization. The willingness of a customer to wait for backlogging during a shortage period declines with the length of the waiting time using Particle Swarm Optimization. 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 Particle Swarm Optimization. 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 Particle Swarm Optimization. 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 Particle Swarm Optimization. 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 Particle Swarm Optimization. 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 Particle Swarm Optimization.

## References


1. Yadav, A.S. and Swami, A. (2018) Integrated Supply Chain Model For Deteriorating Items With Linear Stock Dependent Demand Under Imprecise And Inflationary Environment. International Journal Procurement Management, Volume 11 No 6.
2. Yadav, A.S. and Swami, A. (2019) An inventory model for non-instantaneous deteriorating items with variable holding cost under two-storage. International Journal Procurement Management, Volume 12 No 6, 2019.
3. Yadav, A.S. and Swami, A. (2019) A Volume Flexible Two-Warehouse Model with Fluctuating Demand and Holding Cost under Inflation International Journal Procurement Management, Volume 12 No 4, 2019.
4. Yadav, A.S., Bansal, K.K., Kumar, J. and Kumar, S. (2019) Supply Chain Inventory Model For Deteriorating Item With Warehouse & Distribution Centres Under Inflation. International Journal of Engineering and Advanced Technology (IJEAT), Volume-8, Issue-2S2.
5. Yadav, A.S., Kumar, J., Malik, M. and Pandey, T. (2019) Supply Chain of Chemical Industry For Warehouse With Distribution Centres Using Artificial Bee Colony Algorithm. International Journal of Engineering and Advanced Technology (IJEAT), Volume-8, Issue-2S2.
6. Pandey, T., Yadav, A.S. and Malik, M. (2019) An Analysis Marble Industry Inventory Optimization Based on Genetic Algorithms and Particle swarm optimization. International Journal of Engineering and Advanced Technology (IJEAT), Volume-7, Issue-6S4.

7. Malik, M., Pandey, T. and Yadav, A.S., (2019) Security Mechanism implemented in Gateway Service Providers. International Journal of Engineering and Advanced Technology (IJEAT), Volume-7, Issue-6S4, April 2019.
8. Kumar, S., Yadav, A.S., Ahlawat, N. and Swami, A. (2019) Supply Chain Management of Alcoholic Beverage Industry Warehouse with Permissible Delay in Payments using Particle Swarm Optimization. International Journal for Research in Applied Science and Engineering Technology (IJRASET), Volume 7Issue VIII.
9. Kumar, S., Yadav, A.S., Ahlawat, N. and Swami, A. (2019) Green Supply Chain Inventory System of Cement Industry for Warehouse with Inflation using Particle Swarm Optimization. International Journal for Research in Applied Science and Engineering Technology (IJRASET), Volume 7Issue VIII.
10. Kumar, S., Yadav, A.S., Ahlawat, N. and Swami, A. (2019) Electronic Components Inventory Model for Deterioration Items with Distribution Centre using Genetic Algorithm. International Journal for Research in Applied Science and Engineering Technology (IJRASET), Volume 7Issue VIII.
11. Yadav, A.S., Swami, A., Ahlawat, N., Bhatt, D. and Kher, G. (2020) Electronic components supply chain management of Electronic Industrial development for warehouse and its impact on the environment using Particle Swarm Optimization Algorithm International Journal Procurement Management. Optimization and Inventory Management, Springer, 2020.
12. Yadav, A.S. and Swami, A. (2018) A partial backlogging production-inventory lot-size model with time-varying holding cost and weibull deterioration International Journal Procurement Management, Volume 11, No. 5.
13. Yadav, A.S., Swami, A. and Kumar, S. (2018) A supply chain Inventory Model for decaying Items with Two Ware-House and Partial ordering under Inflation. International Journal of Pure and Applied Mathematics, Volume 120 No 6.
14. Yadav, A.S., Swami, A. and Kumar, S. (2018) An Inventory Model for Deteriorating Items with Two warehouses and variable holding Cost International Journal of Pure and Applied Mathematics, Volume 120 No 6.
15. Yadav, A.S., Swami, A. and Kumar, S. (2018) Inventory of Electronic components model for deteriorating items with warehousing using Genetic Algorithm. International Journal of Pure and Applied Mathematics, Volume 119 No. 16.
16. Yadav, A.S., Johri, M., Singh, J. and Uppal, S. (2018) Analysis of Green Supply Chain Inventory Management for Warehouse With Environmental Collaboration and Sustainability Performance Using Genetic Algorithm. International Journal of Pure and Applied Mathematics, Volume 118 No. 20.
17. Yadav, A.S., and Kumar, S. (2017) Electronic Components Supply Chain Management for Warehouse with Environmental Collaboration & Neural Networks. International Journal of Pure and Applied Mathematics, Volume 117 No. 17.
18. Yadav, A.S., Taygi, B., Sharma, S. and Swami, A. (2017) Effect of inflation on a two-warehouse inventory model for deteriorating items with time varying demand and shortages International Journal Procurement Management, Volume 10, No. 6.
19. Yadav, A.S., Mahapatra, R.P., Sharma, S. and Swami, A. (2017) An Inflationary Inventory Model for Deteriorating items under Two Storage Systems International Journal of Economic Research, Volume 14 No.9.
20. Yadav, A.S., Sharma, S. and Swami, A. (2017) A Fuzzy Based Two-Warehouse Inventory Model For Non instantaneous Deteriorating Items With Conditionally Permissible Delay In Payment, International Journal of Control Theory And Applications, Volume 10 No.11.
21. Yadav, A.S., (2017) Analysis Of Supply Chain Management In Inventory Optimization For Warehouse With Logistics Using Genetic Algorithm International Journal of Control Theory And Applications, Volume 10 No.10.
22. Yadav, A.S., Swami, A., Kher, G. and Sachin Kumar (2017) Supply Chain Inventory Model for Two Warehouses with Soft Computing Optimization International Journal of Applied Business and Economic Research Volume 15 No 4.
23. Yadav, A.S., Mishra, R., Kumar, S. and Yadav, S. (2016) Multi Objective Optimization for Electronic Component Inventory Model & Deteriorating Items with Two-warehouse using Genetic Algorithm International Journal of Control Theory and applications, Volume 9 No.2.
24. Yadav, A.S., (2017) Modeling and Analysis of Supply Chain Inventory Model with two-warehouses and Economic Load Dispatch Problem Using Genetic Algorithm International Journal of Engineering and Technology (IJET) Volume 9 No 1.
25. Yadav, A.S., Swami, A. and Kher, G. (2018) Particle Swarm optimization of inventory model with two-warehouses Asian Journal of Mathematics and Computer Research, Volume 23 No.1.
26. Yadav, A.S., Maheshwari, P., Swami, A. and Pandey, G. (2018) A supply chain management of Hazardous Substance industry for deteriorating items with warehouse using genetic algorithm Selforganizology, Volume 5 No.1-2.

27. Yadav, A.S., (2017) Analysis Of Seven Stages Supply Chain Management In Electronic Component Inventory Optimization For Warehouse With Economic Load Dispatch Using GA And PSO Asian Journal Of Mathematics And Computer Research, volume 16 No.4 2017.
28. Yadav, A.S., Garg, A., Gupta, K. and Swami, A. (2017) Multi-objective Genetic algorithm optimization in Inventory model for deteriorating items with shortages using Supply Chain management IPASJ International journal of computer science (IIJCS) Volume 5, Issue 6.
29. Yadav, A.S., Garg, A., Swami, A. and Kher, G. (2017) A Supply Chain management in Inventory Optimization for deteriorating items with Genetic algorithm
30. International Journal of Emerging Trends & Technology in Computer Science (IJETTCS) Volume 6, Issue 3.
31. Yadav, A.S., Maheshwari, P., Garg, A., Swami, A. and Kher, G. (2017) Modeling & Analysis of Supply Chain management in Inventory Optimization for deteriorating items with Genetic algorithm and Particle Swarm optimization International Journal of Application or Innovation in Engineering & Management (IJAIEM) Volume 6, Issue 6.
32. Yadav, A.S., Garg, A., Gupta, K. and Swami, A. (2017) Multi-objective Particle Swarm optimization and Genetic algorithm in Inventory model for deteriorating items with shortages using Supply Chain management International Journal of Application or Innovation in Engineering & Management (IJAIEM) Volume 6, Issue 6.
33. Yadav, A.S., Maheshwari, P., Swami, A. and Kher, G. (2017) Soft Computing Optimization of Two Warehouse Inventory Model With Genetic Algorithm. Asian Journal of Mathematics and Computer Research volume 19 No.4.
34. Yadav, A.S., Swami, A. and Kher, G. (2017) Multi-Objective Genetic Algorithm Involving Green Supply Chain Management International Journal for Science and Advance Research In Technology (IJSART) Volume 3 Issue 9.
35. Yadav, A.S., Swami, A. and Kher, G. (2017) Multi-Objective Particle Swarm Optimization Algorithm Involving Green Supply Chain Inventory Management International Journal for Science and Advance Research In Technology (IJSART) Volume 3 Issue 9.
36. Yadav, A.S., Swami, A. and Pandey, G. (2017) Green Supply Chain Management for Warehouse with Particle Swarm Optimization Algorithm International Journal for Science and Advance Research In Technology (IJSART) Volume 3 Issue 10.
37. Yadav, A.S., Swami, A., Kher, G. and Garg, A. (2017) Analysis of seven stages supply chain management in electronic component inventory optimization for warehouse with economic load dispatch using genetic algorithm Selforganizology, Volume 4 No.2.
38. Yadav, A.S., Maheshwari, P., Swami, A. and Garg, A. (2017) Analysis of Six Stages Supply Chain management in Inventory Optimization for warehouse with Artificial bee colony algorithm using Genetic Algorithm Selforganizology, Volume 4 No.3.
39. Yadav, A.S., Swami, A., C. B. Gupta, and Garg, A. (2016) Analysis of Electronic component inventory Optimization in Six Stages Supply Chain management for warehouse with ABC using genetic algorithm and PSO Selforganizology, Volume 4 No.4.
40. Yadav, A.S., Swami, A., Kumar, S. and Singh, R.K. (2016) Two-Warehouse Inventory Model for Deteriorating Items with Variable Holding Cost, Time-Dependent Demand and Shortages IOSR Journal of Mathematics (IOSR-JM) Volume 12, Issue 2 Ver. IV.
41. Yadav, A.S., Sharam, S. and Swami, A. (2016) Two Warehouse Inventory Model with Ramp Type Demand and Partial Backordering for Weibull Distribution Deterioration International Journal of Computer Applications Volume 140 –No.4.
42. Yadav, A.S., Swami, A. and Singh, R.K. (2016) A two-storage model for deteriorating items with holding cost under inflation and Genetic Algorithms International Journal of Advanced Engineering, Management and Science (IJAEMS) Volume -2, Issue-4.
43. Yadav, A.S., Maheshwari, P. and Swami, A. (2016) Analysis of Genetic Algorithm and Particle Swarm Optimization for warehouse with Supply Chain management in Inventory control International Journal of Computer Applications Volume 145 –No.5.
44. Swami, A., Singh, S. R., Pareek, S. and Yadav, A.S. (2015) Inventory policies for deteriorating item with stock dependent demand and variable holding costs under permissible delay in payment International Journal of Application or Innovation in Engineering & Management (IJAIEM) Volume 4, Issue 2.
45. Swami, A., Pareek, S. , , S. R. Singh and Yadav, A.S. (2015) An Inventory Model With Price Sensitive Demand, Variable Holding Cost And Trade-Credit Under Inflation International Journal of Current Research Volume 7, Issue 06.

46. Gupta, K., Yadav, A.S., Garg, A. and Swami, A. (2015) A Binary Multi-Objective Genetic Algorithm &PSO involving Supply Chain Inventory Optimization with Shortages, inflation International Journal of Application or Innovation in Engineering & Management (IJAIEM) Volume 4, Issue 8.
47. Yadav, A.S., Gupta, K., Garg, A. and Swami, A. (2015) A Soft computing Optimization based Two Ware-House Inventory Model for Deteriorating Items with shortages using Genetic Algorithm International Journal of Computer Applications Volume 126 – No.13.
48. Gupta, K., Yadav, A.S. and Garg, A. (2015) Fuzzy-Genetic Algorithm based inventory model for shortages and inflation under hybrid & PSO IOSR Journal of Computer Engineering (IOSR-JCE) Volume 17, Issue 5, Ver. I.
49. Yadav, A.S., Gupta, K., Garg, A. and Swami, A. (2015) A Two Warehouse Inventory Model for Deteriorating Items with Shortages under Genetic Algorithm and PSO International Journal of Emerging Trends & Technology in Computer Science (IJETTCS) Volume 4, Issue 5(2).
50. Yadav, A.S. and Swami, A. (2014) Two-Warehouse Inventory Model for Deteriorating Items with Ramp-Type Demand Rate and Inflation. American Journal of Mathematics and Sciences Volume 3 No-1.
51. Yadav, A.S. and Swami, A. (2013) Effect of Permissible Delay on Two-Warehouse Inventory Model for Deteriorating items with Shortages. International Journal of Application or Innovation in Engineering & Management (IJAIEM) Volume 2, Issue 3.
52. Yadav, A.S., Swami, A. (2013) A Two-Warehouse Inventory Model for Decaying Items with Exponential Demand and Variable Holding Cost. International of Inventive Engineering and Sciences (IJIES) Volume-1, Issue-5.
53. Yang, X.S. (2010) "Engineering Optimization – An Introduction to Metaheuristic Applications" John Wiley & Sons, Hoboken, New Jersy.
54. Lee, K.Y. and El-Sharkawi, M.A. (2008) "Modern Heuristic Optimization Techniques" IEEE press and Wiley – InterScience, New Jersy.
55. Goldberg D.E. (1989) "Genetic Algorithms in Search, Optimization, and Machine Learning", Kluwer Academic Publishers, Boston, 1989.
56. Storn, R. and Price, K. (1997) "Differential Evolution - a Simple and Efficient Heuristic for Global Optimization over Continuous Spaces," Journal of Global Optimization, Vol. 11, pp. 341–359.
57. Kennedy, J. and Eberhart, R. C. (1995) "Particle swarm optimization," Proceedings of IEEE International Conference on Neural Networks, pp. 1942–1948.
58. Kirkpatrick, S., Gelatt, C., and Vecchi, M. (1983) "Optimization by simulated annealing," Science, Vol. 220, pp. 671–680.
59. Chandrasekar, K. and Ramana, N.V. (2012) Performance Comparison of GA, DE, PSO and SA Approaches in Enhancement of Total Transfer Capability using FACTS Devices, Journal of Electrical Engineering & Technology Vol. 7, No. 4, pp. 493-500.