*Article*

# A Green supply chain management of Auto industry for inventory model with distribution centers using Particle Swarm Optimization

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**Abstract**
Green supply chain inventory optimization of Auto industry and Particle Swarm Optimization (PSO) for deteriorating items in a manufacture of Auto industry, warehouse of Auto industry, three distribution centers of Auto industry, and three Retailer's of Auto industry environment using Particle Swarm Optimization (PSO). Demand is assumed to be known and constant. Shortages of Auto industry are not allowed and apply inflation of Auto industry. The distribution centers of Auto industry is used to store the excess units over the fixed capacity of the distribution centers of Auto industry. Further Green supply chain inventory optimization of Auto industry and Particle Swarm Optimization (PSO) dispatching policies has been investigated in different scenarios in the model.

**Keywords** Green supply chain of Auto industry; green inventory optimization of Auto industry; Green Retailer's of Auto industry; green distribution centers of Auto industry; Particle Swarm Optimization (PSO).

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## 1 Introduction

Inventory control, otherwise known as stock control, is used to show how much stock have to maid available at any time, and how tracks are kept for it. It applies to every item that uses to produce a product or service, from raw materials to finished goods. It covers stock at every stage of the Manufacturing process, from purchase and delivery to using and re-ordering the stock. Efficient stock control allows an organization/ industry/company to have the right amount of stock in the right place at the right time. It ensures that capital is not tied up unnecessarily, and protects manufacturing if problems arise with the Green supply chain. Inventory control is the techniques of maintaining stock-items at desired levels. The purpose of all inventory models is to minimize inventory costs. As a result of the inventory model, a designer of air-condition machine decided to redesign its old model machine to enhance its working efficiency and reduce inventory costs in meeting a global market for its air-condition machines.

Inventory is held throughout the Green supply chain in the form of raw materials, work in process and finished goods. Inventory exists in the Green supply chain because of a mismatch between supply and demand. This mismatch is intentional at a manufacturer, where it is economical to manufacture in large lots that are then stored for future sales. The mismatch is also intentional at a retail store where inventory is held in anticipation of future demand. Inventory is a major source of cost in a Green supply chain and has a huge impact on responsiveness. An important role that inventory plays in the Green supply chain is (1) to increase the amount of demand that can be satisfied by having the product ready and available when the customer wants it. (2) To reduce cost by exploiting economics of scale that may exist during Manufacturing and distribution. (3) To support a firm's competitive strategy. If a firm's competitive strategy requires very high level of responsiveness, a company can achieve this responsiveness by locating large amounts of inventory close to a customer. Conversely, a company can also use inventory to become more efficient by reducing inventory through centralized stocking.

## 2 Related Works

Narmadha at al. (2010) proposed multi-product inventory optimization using uniform crossover genetic algorithm. Radhakrishnan et al. (2009) given an inventory optimization in supply chain management using genetic algorithm. Singh and Kumar (2011) given an inventory optimization in efficient supply chain management. Priya and Iyakutti (2011) proposed Web based Multi Product Inventory Optimization using Genetic Algorithm. Thakur and Desai (2013) made the inventory analysis using genetic algorithm in supply chain management. Khalifehzadeh et al. (2015) presented a four-echelon supply chain network design with shortage. Kannan et al. (2010) discussed a genetic algorithm approach for solving a closed loop supply chain model. Jawahar and Balaji (2009) proposed a genetic algorithm for the two-stage supply chain distribution problem associated with a fixed charge. Zhang et al. (2013) presented a modified multi-criterion optimization genetic algorithm for order distribution in collaborative supply chain. Che and Chiang (2010) proposed a modified Pareto genetic algorithm for multi-objective build-to-order supply chain planning with product assembly. Yimer and Demirli (2010) presented a genetic approach to two-phase optimization of dynamic supply chain scheduling. Wang et al. (2011) proposed location and allocation decisions in a two-echelon supply chain with stochastic demand. Humphreys et al. (2009) tried to reduce the negative effects of sales promotions in supply chains using genetic algorithms. Sherman et al. (2010) given a production modelling with genetic algorithms for a stationary pre-cast supply chain. Ye et al. (2010) proposed some improvements on adaptive genetic algorithms for reliability-related applications. Guchhait et al. (2010) presented multi-item inventory model of breakable items with stock-dependent demand under stock and time dependent breakability rate. Changdar et al. (2015) given an improved genetic algorithm based approach to solve constrained knapsack problem in fuzzy environment. Sourirajan et al. (2009) presented a genetic algorithm for a single product network design model with lead time and safety stock considerations. Jiang et al. (2015) given Joint optimization of preventive maintenance and inventory policies for multi-unit systems subject to deteriorating spare part inventory. Dey et al. (2008) proposed two storage inventory problem with dynamic demand and interval valued lead-time over finite time horizon under inflation and time-value of money. Jawahar and Balaji (2012) proposed a genetic algorithm based heuristic to the multi-period fixed charge distribution problem. Pasandideh et al. (2010) given a parameter-tuned genetic algorithm for multi-product economic production quantity model with space constraint, discrete delivery orders and shortages. Yadav et al. (2016) proposed a cooperative two-warehouse inventory model for deteriorating items with variable holding cost, time-dependent demand and shortages. Singh et al. (2016) proposed a two-warehouse model for deteriorating items with holding cost under particle swarm optimization. Yadav et al. (2016) analyzed a multi objective optimization for electronic component inventory model & deteriorating items with two-warehouse using genetic algorithm. Sharma et al. (2016) focused an optimal ordering policy for non-instantaneous deteriorating items with conditionally permissible delay in payment under two storage management. Yadav et al. (2016) analyzed genetic algorithm and particle swarm optimization for warehouse with supply chain management in inventory control. Yadav et al. (2018) provided a supply chain management of chemical industry for deteriorating items with warehouse using genetic algorithm. In addition, Zhang (2014, 2016, 2018) discussed particle swarm optimization and other self-organization techniques.

## 3 Assumptions and Notations

### 3.1 Assumptions

1. The Manufacturing rate is $\omega_1 t_i$ are linear function of time.
2. The demand rate is $D_1 t_i$ are linear function of time.
3. The holding cost is $Ht_i$ are linear function of time.

### 3.2 Notations

$\theta_1$ = Green Scale parameter of amelioration rate.
$\theta_2$ = Green Shape parameter of amelioration rate.
$\alpha_{GRM} + 3$ = Raw material of Auto industry Scale parameter for the deterioration rate.
$\beta_{GRM} + 2$ = Raw material of Auto industry Shape parameter for the deterioration rate.
$\alpha_{GM} + 3$ = G. M. of Auto industry Scale parameter for the deterioration rate.
$\beta_{GM} + 2$ = G. M. of Auto industry Shape parameter for the deterioration rate.
$\alpha_{DC} + 3$ = Green D. C of Auto industry Scale parameter for the deterioration rate.
$\beta_{DC} + 2$ = Green D. C of Auto industry Shape parameter for the deterioration rate.
$\alpha_{R} + 3$ = Green Retailer's of Auto industry Scale parameter for the deterioration rate.
$\beta_{R} + 2$ = Green Retailer's of Auto industry Shape parameter for the deterioration rate.
$GI_{GRi}(t_i)$ = Green Raw material'sof Auto industry inventory level
$GI_{GMi}(t_i)$ = Green Manufacturingof Auto industry finished goods inventory level .
$GI_{GDCi}(t_i)$ = Green Distributor center of Auto industry finished goods inventory level .
$GI_{GRi}(t_i)$ = Green Retailer's of Auto industry finished goods inventory level .
$GTC_{GRM}$ = Green Raw material's of Auto industry net present total cost per unit time.
$GTC_{GM}$ = Green Manufacturing of Auto industry net present total cost per unit time.
$GTC_{GDC}$ = Green D. C of Auto industrynet present total cost per unit time.
$GTC_{GR}$ = Green Retailer's of Auto industry net present total cost per unit time.

## 4 Mathematics Model in Green Supply Chain Inventory Control

The proposed method uses the Particle Swarm Optimization (PSO) to study the stock level that needs essential Green inventory control. This is the pre-requisite idea that will make any kind of Green inventory control of Auto industry effective. For this purpose, we are algorithm method as assistance. In practice, the Green supply chain is of length m, means having m number of members in Green supply chain of Auto industry such as Green Raw material of Auto industry, Green Manufacture of Auto industry, and Green Distribution centers of Auto industry. Each Green distribution center of Auto industry further comprises of several Green Retailer's but as stated in the example case, each Green Distribution center of Auto industry is having one agent. So, in aggregate there are Green Retailers' of Auto industry, Green Retailer's of Auto industry for Green Distribution Center-1 of Auto industry so on. Here, for instance we are going to use a Green supply chain of Auto industry that is illustrated in the Fig. 1.

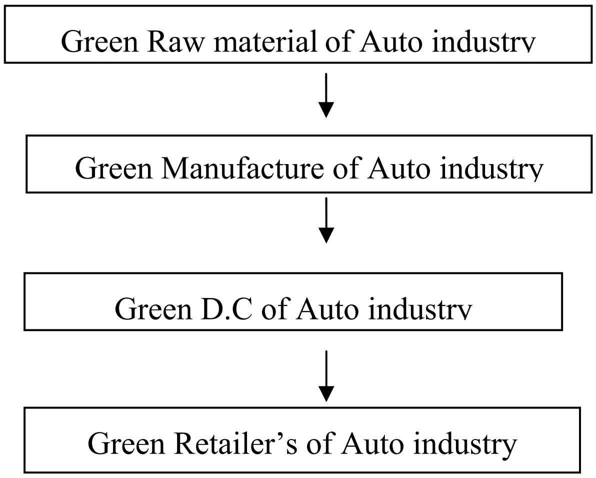


**Fig. 1** Green supply chain of Auto industry.

- **Green Raw materials of Auto industry:**

$$GTC_{GRM} = \left[ \frac{1}{T} \left[ \sum_{t_1=0}^{T_1} \left\{ \begin{array}{l} \left[ \theta_1 \theta_2 t_1^{\theta_2 - 1} I_{GRM}(t_1) - (\alpha_{GRM} + 3)(\beta_{GRM} + 2) t_1^{\beta GRM} I_{GRM}(t_1) \right] + \left( GR_0 t_1 \right) \\ + \left[ Ht_1 \{ \theta_1 \theta_2 t_1^{\theta_2 - 1} I_{GRM}(t_1) - (\alpha_{GRM} + 3)(\beta_{GRM} + 2) t_1^{\beta GR} I_{GR}(t_1) \} \right] \end{array} \right\} \right] \right] \quad (1)$$

- **Green Manufacturing of Auto industry:**

$$GTC_{GM} = \left[ \frac{1}{T} \left[ \sum_{t_2=0}^{T_2} \left\{ \begin{array}{l} \left[ \omega_1 t_2 - D_1 t_2 - (\alpha_{GM} + 3)(\beta_{GM} + 2) t_2^{\beta GM} I_{GM}(t_2) \right] + \left( GM_0 t_2 \right) \\ + \left[ Ht_2 \left\{ \omega_1 t_2 - D_1 t_2 - (\alpha_{GM} + 3)(\beta_{GM} + 2) t_2^{\beta GM} I_{GM}(t_2) \right\} \right] \end{array} \right\} \right] \right] \quad (2)$$

- **Green Distributor center of Auto industry:**

$$GTC_{GDC} = \left[ \frac{1}{T} \left[ \sum_{t_3=0}^{T_3} \left\{ \begin{array}{l} \left[ \omega_1 t_3 - D_1 t_3 - (\alpha_{GDC} + 3)(\beta_{GDC} + 2) t_3^{\beta GDC} I_{GDC}(t_3) \right] + \left( C_0 t_3 \right) \\ + \left[ Ht_5 \left\{ \omega_1 t_3 - D_1 t_3 - (\alpha_5 + 3)(\beta_{GDC} + 2) t_3^{\beta GDC} I_{GDC}(t_3) \right\} \right] \end{array} \right\} \right] \right] \quad (3)$$

- **Green Retailer's of Auto industry:**

$$GTC_{GR} = \left[ \frac{1}{T} \left[ \sum_{t_4=0}^{T4} \left\{ \begin{matrix} \left[ -D_1 t_4 - (\alpha_{GR} + 3)(\beta_{GR} + 1) t_4^{\beta GR} I_{GR}(t_4) \right] + \left( GRt_4 \right) \\ + \left[ Ht_4 \left\{ -D_1 t_4 - (\alpha_{GR} + 3)(\beta_{GR} + 2) t_4^{\beta GR} I_{GR}(t_4) \right\} \right] \end{matrix} \right\} \right] \right] \quad (4)$$

$$GTC = \left[ \frac{GTC_{GRM} + GTC_{GM} + GTC_{GDC} + GTC_{GR}}{T} \right] \quad (5)$$

$$TC = \left[ \frac{1}{T} \left\{ \begin{matrix} \left[ \sum_{t_1=0}^{T_1} \left\{ \begin{matrix} \left[ \theta_1 \theta_2 t_1^{\theta_2 - 1} I_{GRM}(t_1) - (\alpha_{GRM} + 3)(\beta_{GRM} + 2) t_1^{\beta GRM} I_{GRM}(t_1) \right] + \left( GR_0 t_1 \right) \\ + \left[ Ht_1 \{ \theta_1 \theta_2 t_1^{\theta_2 - 1} I_{GRM}(t_1) - (\alpha_{GRM} + 3)(\beta_{GRM} + 2) t_1^{\beta GR} I_{GR}(t_1) \} \right] \end{matrix} \right\} \right] + \\ \left[ \sum_{t_2=0}^{T_2} \left\{ \begin{matrix} \left[ \omega_1 t_2 - D_1 t_2 - (\alpha_{GM} + 3)(\beta_{GM} + 2) t_2^{\beta GM} I_{GM}(t_2) \right] + \left( GM_0 t_2 \right) \\ + \left[ Ht_2 \left\{ \omega_1 t_2 - D_1 t_2 - (\alpha_{GM} + 3)(\beta_{GM} + 2) t_2^{\beta GM} I_{GM}(t_2) \right\} \right] \end{matrix} \right\} \right] + \\ \left[ \sum_{t_3=0}^{T_3} \left\{ \begin{matrix} \left[ \omega_1 t_3 - D_1 t_3 - (\alpha_{GDC} + 3)(\beta_{GDC} + 2) t_3^{\beta GDC} I_{GDC}(t_3) \right] + \left( C_0 t_3 \right) \\ + \left[ Ht_5 \left\{ \omega_1 t_3 - D_1 t_3 - (\alpha_5 + 3)(\beta_{GDC} + 2) t_3^{\beta GDC} I_{GDC}(t_3) \right\} \right] \end{matrix} \right\} \right] + \\ \left[ \sum_{t_4=0}^{T4} \left\{ \begin{matrix} \left[ -D_1 t_4 - (\alpha_{GR} + 3)(\beta_{GR} + 1) t_4^{\beta GR} I_{GR}(t_4) \right] + \left( GRt_4 \right) \\ + \left[ Ht_4 \left\{ -D_1 t_4 - (\alpha_{GR} + 3)(\beta_{GR} + 2) t_4^{\beta GR} I_{GR}(t_4) \right\} \right] \end{matrix} \right\} \right] \end{matrix} \right\} \right] \quad (6)$$

## 5 Proposed Particle Swarm Optimization Algorithm

Particle Swarm Optimization (PSO) introduced by Kennedy and Eberhart in 1995 is a population based evolutionary computation technique. It has been developed by simulating bird flocking fish schooling or sociological behaviour of a group of people artificially. Here the population of solution is called swarm which is composed of a number of agents known as particles. Each particle is treated as point in d-dimensional search space which modifies its position according to its own flying experience and that of other particles present in the swarm. The algorithm starts with a population (swarm) of random solutions (particles). Each particle is assigned a random velocity and alloHered to move in the problem space. The particles have memory and each of them keeps track of its previous (local) best position.

K: =0

$\{L_s, E_s, H_s, J_s\}_{s=1}^{S}$ := initialize()

For x: = 1: U

For b: = 1: S

For r: = 1: R

$e_{sc}^{(x+1)} = ye_{sc}^{x} + c_1 l_1 [J_{sc} - l_{sc}^{x}] + c_2 d_2 [H_{sc} - l_{sc}^{x}]$

$D_s^{x+1} = D_s^x + dE_s^x + \in^x$

end

$D_s$: = enforce Constraints(S )

$Y_s$= f($L_s$ )

If $D_s$ ⋠e ∀ e ∈ K

K:= {e ∈K/ e⊀$L_s$ }

K:= K∪$L_s$

End

End

If $L_s$ ≤$J_s$ ∨ (S$L_s$⊀$J_s$ ∧ $J_s$ ⊀ $D_s$)

$J_s$ := $L_s$

End

$H_s$ := selectGuide(S , A)

End

**6 Implementation of System**

In the proposed algorithm steps is applied on mathematical results obtained from the mathematical inventory model. It provides best cost solution and optimizes the results. MATLAB is used to implement the proposed work. MATLAB stands for matrix programming language which was developed by Math Works. It is a programming language that makes algebra programming simple. MATLAB is a fourth-generation high level programming language that provides an interactive environment for computation, visualization and programming. Functions of MATLAB that are used in proposed work are:

- Zeros: it will create an array of all zeros.
- Rand: It will generate array of random numbers.
- Sum: Sum of array elements.
- Ones: Create an array of all ones.
- Consume: It returns cumulative sum of all elements.
- Cost function: This function is used to optimize the results.
- Floor: Rounds the elements to the nearest integers less than or equal to value.
- Plot: To plot graphs.

**7 Numerical Analysis**

The following randomly chosen data in appropriate units has been used to find the optimal solution and validate the model of the three players the Manufacturing, the distributor and the retailer. The data are Manufacturing=700, distributor=750 and Retailer=600 given as.

The total 10 problem instances are run for the binary PSO with holding cost = € 4.73, ordering cost =€ 140, in order to compare the results with those optimal by the Wagner-Whit in algorithm. For each problem instance, 10 replications are conducted. Minimum, maximum, average, and standard deviation are given together with the CPU times.

The computational optimal solutions of the models are shown in Table 1 and 2.

**Table 1** Total relevant cost.

| Cost function | $t_1^*$ | $t_2^*$ | $T^*$ | Total relevant cost | Particle Swarm optimization |
|---|---|---|---|---|---|
| $T^c(t_1^*, \mathrm{T})$ | 1254.47 | 17136.70 | 16597.24 | 5283.27 | 4372.16 |

**Table 2** PSO Results.

| P | WW | PSO | | | |
|---|---|---|---|---|---|
| | OPT | BEST | MAX | AVG | STD |
| 1 | 72.90 | 62.90 | 52.90 | 42.90 | 32.90 |
| 2 | 72.85 | 62.85 | 52.85 | 42.85 | 32.85 |
| 3 | 72.80 | 62.80 | 52.80 | 42.80 | 32.80 |
| 4 | 72.75 | 62.75 | 52.75 | 42.75 | 32.75 |
| 5 | 72.70 | 62.70 | 52.70 | 42.70 | 32.70 |
| 6 | 72.65 | 62.65 | 52.65 | 42.65 | 32.65 |
| 7 | 72.60 | 62.60 | 52.60 | 42.60 | 32.60 |
| 8 | 72.55 | 62.55 | 52.55 | 42.55 | 32.55 |
| 9 | 72.50 | 62.50 | 52.50 | 42.50 | 32.50 |
| 10 | 72.45 | 62.45 | 52.45 | 42.45 | 32.45 |

## 8 Conclusion

In this paper an integrated Manufacturing of Auto industry Green supply chain inventory model of Auto industry with linear Green Manufacturing of Auto industry and demand rate of Auto industry has been developed for deteriorating item and economic load dispatch using Particle Swarm Optimization (PSO) is a significant component of Green supply chain management of Auto industry. In this model the deterioration, the multiple deliveries and the time discounting are considered from the perspective Green supply chain of Auto industry, Green Raw material of Auto industry, Green Storage of Auto industry, Green Manufacture of Auto industry, Green warehouse of Auto industry, Green distribution centers of Auto industry as well as Green Retailer's of Auto industry using Particle Swarm Optimization (PSO) and MATLAB.

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