Modeling &Analysis of Supply Chain management in Inventory Optimization for deteriorating items with Genetic algorithm and Particle Swarm optimization

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Abstract

Six Stages - 10 Member supply chain inventory optimization and Genetic algorithm for deteriorating items in a manufacture, warehouse, three distribution centers, and three Retailer's environment and economic load dispatch using Genetic algorithm and Particle Swarm optimization. Demand is assumed to be known and constant. Shortages are not allowed and apply inflation. A warehouse is used to store the excess units over the fixed capacity of the two distribution centers. Further the application of Six Stages - 10 Member supply chain inventory system using Genetic algorithm and Particle Swarm optimization dispatching policies has been investigated in different scenarios in the model. Comparative study of two models has also been performed with the help of a numerical example. A comprehensive sensitivity analysis has also been carried out to advocate the implication of Six Stages - 10 Member supply chain inventory system using Genetic algorithm and Particle Swarm optimization dispatch policy.

Keywords:- supply chain, inventory optimization, warehouse, three Retailer's, three distribution centers, Genetic algorithm and Particle Swarm optimization.

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 production 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 production if problems arise with the 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 supply chain in the form of raw materials, work in process and finished goods. Inventory exists in the 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 supply chain and has a huge impact on responsiveness. An important role that inventory plays in the 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 production 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.
Discussions so far were limited to GA that handled the optimization of a single parameter. The optimization criteria are represented by fitness functions and are used to lead towards an acceptable solution. A typical single objective optimization problem is the TSP. There the sole optimization criterion is the cost of the tour undertaken by the salesperson and this cost is to be minimized. However, In real life we often face problem which require simultaneous optimization of several criteria. For example, in VLSI circuit design the critical parameters are chip area power consumption delay fault tolerance etc. While designing a VLSI circuit the designer may like to minimize area power consumption and delay while at the same time would like to maximize fault tolerance. The problem gets more complicated when the optimizing criteria are conflicting. For instance an attempt to design low-power VLSI circuit may affect its fault tolerance capacity adversely. Such problems are known as multi-objective optimization (MOO). Multi-objective optimization is the process of systematically and simultaneously optimizing a number of objective functions. Multiple objective problems usually have conflicting objectives which prevents simultaneous optimization of each objective. As GAs are population based optimization processes they are inherently suited to solve MOO problem. However traditional GAs are to be customized to accommodate such problem. This is achieved by using specialized fitness functions as well as incorporating methods promoting solution diversity. Rest of this section presents the features of multi-objective GAs.

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 behavior 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 allowed to move in the problem space. The particles have memory and each of them keeps track of its previous (local) best position.

2. Related Works

Ajay Singh Yadav (2017) The purpose of the proposed study is to give a new dimension on warehouse with logistics using genetic algorithm processes in supply chain in inventory optimization to describe the certain and uncertain market demand which is based on supply reliability and to develop more realistic and more flexible models. we hope that the proposed study has a great potential to solve various practical tribulations related to the warehouse with logistics using genetic algorithm processes in supply chain in inventory optimization and also provide a general review for the application of soft computing techniques like genetic algorithms to use for improve the effectiveness and efficiency for various aspect of warehouse with logistics control using genetic algorithm.

Narmadha at. al. (2010) proposed inventory management is considered to be an important field in Supply Chain Management because the cost of inventories in a supply chain accounts for about 30% of the value of the product. The service provided to the customer eventually gets enhanced once the efficient and effective management of inventory is carried out all through the supply chain. The precise estimation of optimal inventory is essential since shortage of inventory yields to lost sales, while excess of inventory may result in pointless storage costs. Thus the determination of the inventory to be held at various levels in a supply chain becomes inevitable so as to ensure minimal cost for the supply chain. The minimization of the total supply chain cost can only be achieved when optimization of the base stock level is carried out at each member of the supply chain. This paper deals with the problem of determination of base-stock levels in a ten member serial supply chain with multiple products produced by factories using Uniform Crossover Genetic Algorithms. The complexity of the problem increases when more distribution centers and agents and multiple products were involved. These considerations leading to very complex inventory management process has been resolved in this work.

Radhakrishnan et. al. (2009) gives a inventory management plays a vital role in supply chain management. The service provided to the customer eventually gets enhanced once the efficient and effective management of inventory is carried out all through the supply chain. Thus the determination of the inventory to be held at various levels in a supply chain becomes inevitable so as to ensure minimal cost for the supply chain. Minimizing the total supply chain cost is meant for minimizing holding and shortage cost in the entire supply chain. The minimization of the total supply chain cost can only be achieved when optimization of the base stock level is carried out at each member of the supply chain. A serious issue in the implementation of the same is that the excess stock level and shortage level is not static for every period. In this paper, we have developed a new and efficient approach that works on Genetic Algorithms in order to distinctively determine the most probable excess stock level and shortage level required for inventory optimization in the supply chain such that the total supply chain cost is minimized.

Singh and Kumar (2011) gives a Optimal inventory control is one of the significant tasks in supply chain management. The optimal inventory control methodologies intend to reduce the supply chain cost by controlling the inventory in an effective manner, such that, the SC members will not be affected by surplus as well as shortage of inventory. In this paper, we propose an efficient approach that effectively utilizes the Genetic Algorithm for optimal inventory control. This paper reports a method based on genetic algorithm to optimize inventory in supply chain management. We focus specifically on determining the most probable excess stock level and shortage level required for inventory optimization in the supply chain so that the total supply chain cost is minimized .We apply our methods on three stage supply chain model studied for optimization.

Priya and Iyakutti (2011) presents an approach to optimize the reorder level (ROL) in the manufacturing unit taking consideration of the stock levels at the factory and the distribution centers of the supply chain, which in turn helps the production unit to optimize the production level and minimizing the inventory holding cost. Genetic algorithm is used for the optimization in a multi product, multi level supply chain in a web enabled environment. This prediction of optimal ROL enables the manufacturing unit to overcome the excess/ shortage of stock levels in the upcoming period.

Thakur and Desai (2013) a study With the dramatic increase in the use of the Internet for supply chain-related activities, there is a growing need for services that can analyze current and future purchases possibilities as well as current and future demand levels and determine efficient and economical strategies for the procurement of direct goods. Such solutions must take into account the current quotes offered by suppliers, likely future prices, projected demand, and storage costs in order to make effective decisions on when and from whom to make purchases. Based on demand trends and projections, there is typically a target inventory level that a business hopes to maintain. This level is high enough to be able to meet fluctuations in demand, yet low enough that unnecessary storage costs are minimized. Hence there is a necessity of determining the inventory to be held at different stages in a supply chain so that the total supply chain cost is minimized. Minimizing the total supply chain cost is meant for minimizing holding and shortage cost in the entire supply chain. This inspiration of minimizing Total Supply Chain Cost could be done only by optimizing the base stock level at each member of the supply chain which is very dynamic. A novel and efficient approach using Genetic Algorithm has been developed which clearly determines the most possible excess stock level and shortage level that is needed for inventory optimization in the supply chain so as to minimize the total supply chain cost.

Khalifehzadeh et. al. (2015) presented a four-echelon supply chain network design with shortage: Mathematical modelling and solution methods. Kannan et. al. (2010) Discuss a genetic algorithm approach for solving a closed loop supply chain model: A case of battery recycling. 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. Sarrafha et. al. Discuss (2015) A bi-objective integrated procurement, production, and distribution problem of a multi-echelon supply chain network design: A new tuned MOEA. Taleizadeh et. al. (2011) gives Multiple-buyer multiple-vendor multi-product multi-constraint supply chain problem with stochastic demand and variable lead-time: A harmony search algorithm. Yeh and Chuang (2011) Proposed Using multi-objective genetic algorithm for partner selection in green supply chain problems. 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 – A genetic-algorithm based solution. Humphreys, et. al. (2009) presented Reducing the negative effects of sales promotions in supply chains using genetic algorithms. Sherman et. al. (2010) gives a production modelling with genetic algorithms for a stationary pre-cast supply chain. Ramkumar, et. al. (2011) proposed Erratum to “A genetic algorithm approach for solving a closed loop supply chain model: A case of battery recycling”. 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) gives 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. 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) gives a parameter-tuned genetic algorithm for multi-product economic production quantity model with space constraint, discrete delivery orders and shortages.

3. Assumptions and Notations

Assumptions

1. The amelioration rate of livestock items is a two parameter weibull distribution which is a decreasing function of time and is greater than the deterioration rate which is also a two parameter weibull distribution.
2. The production rate is $(P_0 - P_1 t_i)$ are linear function of time.
3. The demand rate is $(d_0 - d_1 t_i)$ are linear function of time.
4. The holding cost is $(H_0 + H_1 t_i)$ are linear function of time.
5. The production rate is considered greater than the demand rate and the deterioration rate.

6. Lead time is assumed to be negligible.
7. Amelioration and deterioration start when the livestock is bought by the manufacturer.
8. The deteriorated units are not used.
9. Multiple deliveries per order are considered.
10. Only one manufacturer and one warehouse are considered in supply chain.
11. Only one manufacturer and three distributor's center are considered in supply chain.
12. Only one manufacturer and three retailer are considered in supply chain.

Notations

4. Mathematics Model in Supply Chain Inventory control

θ_1 = Scale parameter of amelioration rate.
θ_2 = Shape parameter of amelioration rate.
α_1 = Raw material's Scale parameter for the deterioration rate.
β_1 = Raw material's Shape parameter for the deterioration rate.
α_2 = Storage Scale parameter for the deterioration rate.
β_2 = Storage Shape parameter for the deterioration rate.
α_3 = Manufacturing Scale parameter for the deterioration rate.
β_3 = Manufacturing Shape parameter for the deterioration rate.
α_4 = Warehouse Scale parameter for the deterioration rate.
β_4 = Warehouse Shape parameter for the deterioration rate.
α_5 = Distributor center – 1 Scale parameter for the deterioration rate.
β_5 = Distributor center – 1 Shape parameter for the deterioration rate.
α_6 = Distributor center – 2 Scale parameter for the deterioration rate.
β_6 = Distributor center – 2 Shape parameter for the deterioration rate.
α_7 = Distributor center – 3 Scale parameter for the deterioration rate.
β_7 = Distributor center – 3 Shape parameter for the deterioration rate.
α_8 = Retailer's – 1 Scale parameter for the deterioration rate.
β_8 = Retailer's – 1 Shape parameter for the deterioration rate.
α_9 = Retailer's – 2 Scale parameter for the deterioration rate.
β_9 = Retailer's – 2 Shape parameter for the deterioration rate.
α_{10} = Retailer's – 3 Scale parameter for the deterioration rate.
β_{10} = Retailer's – 3 Shape parameter for the deterioration rate.
$I_{RWi}(t_i)$ = Raw material's inventory level at any time $t_i, 0 \le t_i \le T_i,\ i = 1$.
$I_{Si}(t_i)$ = Storage inventory level at any time $t_i, 0 \le t_i \le T_i,\ i = 2$.
$I_{Mi}(t_i)$ = Manufacturing finished goods inventory level at any time $t_i, 0 \le t_i \le T_i,\ i = 3$.
$I_{Wi}(t_i)$ = Warehouse finished goods inventory level at any time $t_i, 0 \le t_i \le T_i,\ i = 4$.

$I_{DCi}(t_i)$ = Distributor center finished goods inventory level at any time $t_i, 0 \le t_i \le T_i,$ i = 5
$I_{DCi}(t_i)$ = Distributor center finished goods inventory level at any time $t_i, 0 \le t_i \le T_i,$ i = 5
$I_{DCi}(t_i)$ = Distributor center finished goods inventory level at any time $t_i, 0 \le t_i \le T_i,$ i = 5
$I_{Ri}(t_i)$ = Retailer's finished goods inventory level at any time $t_i, 0 \le t_i \le T_i,$ i = 6.
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$I_{Ri}(t_i)$ = Retailer's finished goods inventory level at any time $t_i, 0 \le t_i \le T_i,$ i = 6.
MI_{RM} = Raw material's maximum inventory level.
MI_M = Manufacturing finished goods maximum inventory level.
MI_W = Warehouse finished goods maximum inventory level.
MI_{DC_1} = Distributor center finished goods maximum inventory level.
MI_{DC_2} = Distributor center finished goods maximum inventory level.
MI_{DC_3} = Distributor center finished goods maximum inventory level.
MI_{R_1} = Retailer's finished goods maximum inventory level.
MI_{R_2} = Retailer's finished goods maximum inventory level.
MI_{R_3} = Retailer's finished goods maximum inventory level.
OC_{RM} = Raw material's ordering cost per order cycle.
OC_S = Storage ordering cost per order cycle.
OC_M = Manufacturing ordering cost per order cycle.

The proposed method uses the Genetic algorithm and Particle Swarm optimization to study the stock level that needs essential inventory control. This is the pre-requisite idea that will make any kind of inventory control effective. For this purpose, we are using Economic Load Dispatch algorithm method as assistance. In practice, the supply chain is of length m, means having m number of members in supply chain such as Raw material, Storage, Manufacture, warehouse, Distribution centers, Distribution Center-1, Distribution Center-2 and Distribution Center-3. Each distribution center further comprises of several agents but as stated in the example case, each Distribution center is having one agent. So, in aggregate there are three Retailers', Retailer's-1 for Distribution Center-1, Retailer's-2 for Distribution Center-2 and Retailer's-3 for Distribution Center-3 so on. Here, for instance we are going to use a Six Stages - 10 Member Supply Chain that is illustrated in the figure 1. Our exemplary Six Stages - 10 Member Supply Chain consists of a Raw material, Storage, Manufacture, warehouse, distribution centers-1, distribution centers-2, distribution centers-3, Retailer's-1, Retailer's-2 and Retailer's-3

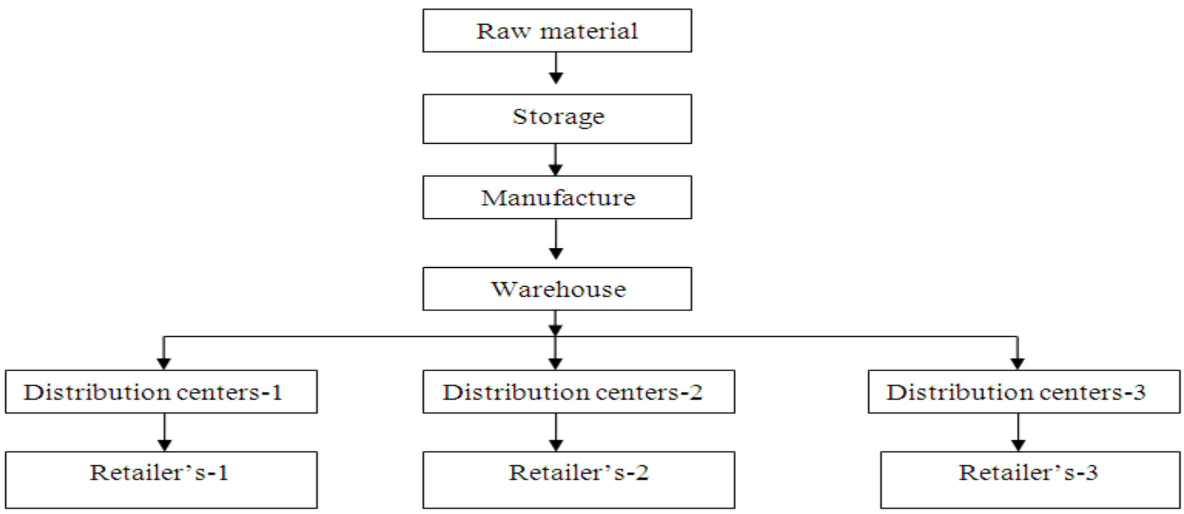

Fig 1. Six Stages - 10 Member Supply Chain

In the Six Stages - 10 Member Supply Chain we are illustrated, the Raw material is the massive stock holding area where the stocks are Storage. The Producer is the massive stock holding area where the stocks are manufactured as per the requirement of the warehouse. Then the warehouse will take care of the stock to be supplied for the distribution center. From the distribution center, the stocks will be moved to the corresponding agents. As earlier discussed, the responsibility of our approach is to predict an optimum stock level by using the past records and so that by using the predicted stock level there will be no excess amount of stocks and also there is less means for any shortage. Hence it can be asserted that our approach eventually gives the amount of stock levels that needs to be held in the Six Stages - 10 Member Supply Chain Raw material, Storage, Manufacture, warehouse, distribution centers-1, distribution centers-2, distribution centers-3, Retailer's-1, Retailer's-2 and Retailer's-3. Each distribution center further comprises of several agents but as stated in the example case, each Distribution center is having one agent. So, in aggregate there are three Retailer's, Retailer's-1 for Distribution Center-1, Retailer's-2 for Distribution Center-2 and Retailer's-3 for Distribution Center-3. In our proposed methodology, we are economic load dispatch using Genetic algorithm and Particle Swarm optimization for finding the optimal value.

4.1. Raw material's inventory system:

$$I_{RM}(t_1) = \theta_1\theta_2 t_1^{\theta_2-1} I_{RM}(t_1) - \alpha_1\beta_1 t_1^{\beta_1-1} I_{RM}(t_1)\ ; 0 \le t_1 \le T_1 \quad (1)$$

4.1.1 Maximum Inventory:-

$$MI_{RM} = \sum_{t_1=0}^{T_1} I_{RM}(t_1) \quad (2)$$

$$MI_{RM} = \sum_{t_1=0}^{T_1} \left[\theta_1\theta_2 t_1^{\theta_2-1} I_{RM}(t_1) - \alpha_1\beta_1 t_1^{\beta_1-1} I_{RM}(t_1)\right] \quad (3)$$

4.1.2 Ordering cost

$$OC_{RM} = \sum_{t_1=0}^{T_1} \left(R_0 + R_1 t_1\right) \quad (4)$$

4.1.3 Holding cost

$$HC_{RM} = \sum_{t_1=0}^{T_1} \left[(H_0 + H_1 t_1) I_{RM}(t_1)\right] \quad (5)$$

$$HC_{RM} = \sum_{t_1=0}^{T_1} \left[(H_0 + H_1 t_1)\{\theta_1\theta_2 t_1^{\theta_2-1} I_{RM}(t_1) - \alpha_1\beta_1 t_1^{\beta_1-1} I_{RM}(t_1)\}\right] \quad (6)$$

4.1.4 Raw material's net present total cost per unit time

$$TC_{RM} = \left[\frac{MI_{RM} + OC_{RM} + HC_{RM}}{T}\right] \quad (7)$$

$$TC_{RM} = \left[\frac{1}{T}\left[\sum_{t_1=0}^{T_1}\left\{\begin{array}{l}\left[\theta_1\theta_2 t_1^{\theta_2-1} I_{RM}(t_1) - \alpha_1\beta_1 t_1^{\beta_1-1} I_{RM}(t_1)\right] + \left(R_0 + R_1 t_1\right) \\ + \left[(H_0 + H_1 t_1)\{\theta_1\theta_2 t_1^{\theta_2-1} I_{RM}(t_1) - \alpha_1\beta_1 t_1^{\beta_1-1} I_{RM}(t_1)\}\right]\end{array}\right\}\right]\right] \quad (8)$$

4.2. Storage inventory system:

$$I_S(t_2) = (d_0 - d_1 t_2) - \alpha_2\beta_2 t_2^{\beta_2-1} I_S(t_2)\ ; 0 \le t_2 \le T_2 \quad (9)$$

4.2.1 Maximum Inventory:-

$$MI_S = \sum_{t_2=0}^{T_2} I_S(t_1) \quad (10)$$

$$MI_S = \sum_{t_2=0}^{T_2}\left[(d_0 - d_1t_2) - \alpha_2\beta_2 t_2^{\beta_2-1} I_S(t_2)\right] \quad (11)$$

4.2.2 Ordering cost

$$OC_S = \sum_{t_2=0}^{T_2}\left(S_0 + S_1t_2\right) \quad (12)$$

4.2.3 Holding cost

$$HC_S = \sum_{t_2=0}^{T_2}\left[(H_0 + H_1t_2) I_S(t_2)\right] \quad (13)$$

$$HC_S = \sum_{t_2=0}^{T_2}\left[(H_0 + H_1t_2)\left\{(d_0 - d_1t_2) - \alpha_2\beta_2 t_2^{\beta_2-1} I_S(t_2)\right\}\right] \quad (14)$$

4.2.4 Raw material's net present total cost per unit time

$$TC_S = \left[\frac{MI_S + OC_S + HC_S}{T}\right] \quad (15)$$

$$TC_S = \left[\frac{1}{T}\left[\sum_{t_2=0}^{T_2}\left\{\begin{matrix}\left[(d_0 - d_1t_2) - \alpha_2\beta_2 t_2^{\beta_2-1} I_S(t_2)\right] + \left(S_0 + S_1t_2\right) \\ + \left[(H_0 + H_1t_2)\left\{(d_0 - d_1t_2) - \alpha_2\beta_2 t_2^{\beta_2-1} I_S(t_2)\right\}\right]\end{matrix}\right\}\right]\right] \quad (16)$$

4.3. Manufacturing finished goods inventory system:

$$I_M(t_3) = (P_0 - P_1t_3) - (d_0 - d_1t_3) - \alpha_3\beta_3 t_3^{\beta_3-1} I_M(t_3)\ ; 0 \le t_3 \le T_3 \quad (17)$$

4.3.1Maximum Inventory:-

$$MI_M = \sum_{t_3=0}^{T_3} I_M(t_3) \quad (18)$$

$$MI_M = \sum_{t_3=0}^{T_3}\left[(P_0 - P_1t_3) - (d_0 - d_1t_3) - \alpha_3\beta_3 t_3^{\beta_3-1} I_M(t_3)\right] \quad (19)$$

4.3.2 Ordering cost

$$OC_M = \sum_{t_3=0}^{T_3}\left(M_0 + M_1t_3\right) \quad (20)$$

4.3.3 Holding cost

$$HC_M = \sum_{t_3=0}^{T_3}\left[(H_0 + H_1t_3) I_M(t_3)\right] \quad (21)$$

$$HC_M = \sum_{t_3=0}^{T_3}\left[(H_0 + H_1t_3)\left\{(P_0 - P_1t_3) - (d_0 - d_1t_3) - \alpha_3\beta_3 t_3^{\beta_3-1} I_M(t_3)\right\}\right] \quad (22)$$

4.3.4 Raw material's net present total cost per unit time

$$TC_M = \left[\frac{MI_M + OC_M + HC_M}{T}\right] \quad (23)$$

$$TC_M = \left[\frac{1}{T} \left[\sum_{t_3=0}^{T_3} \left\{ \begin{array}{l} \left[(P_0 - P_1 t_3) - (d_0 - d_1 t_3) - \alpha_3 \beta_3 t_3^{\beta_3 - 1} I_M(t_3) \right] + \left(M_0 + M_1 t_3 \right) \\ + \left[(H_0 + H_1 t_3) \left\{ (P_0 - P_1 t_3) - (d_0 - d_1 t_3) - \alpha_3 \beta_3 t_3^{\beta_3 - 1} I_M(t_3) \right\} \right] \end{array} \right\} \right] \right] \quad (24)$$

4.4. Warehouse finished goods inventory system:

$$I_W(t_4) = (P_0 - P_1 t_4) - (d_0 - d_1 t_4) - \alpha_4 \beta_4 t_4^{\beta_4 - 1} I_M(t_4) \; ; 0 \le t_4 \le T_4 \quad (25)$$

4.4.1 Maximum Inventory:-

$$MI_W = \sum_{t_4=0}^{T_4} I_W(t_4) \quad (26)$$

$$MI_W = \sum_{t_4=0}^{T_4} \left[(P_0 - P_1 t_4) - (d_0 - d_1 t_4) - \alpha_4 \beta_4 t_4^{\beta_4 - 1} I_M(t_4) \right] \quad (27)$$

4.4.2 Ordering cost

$$OC_W = \sum_{t_4=0}^{T_4} \left(W_0 + W_1 t_4 \right) \quad (28)$$

4.4.3 Holding cost

$$HC_W = \sum_{t_4=0}^{T_4} \left[(H_0 + H_1 t_4) I_W(t_4) \right] \quad (29)$$

$$HC_W = \sum_{t_4=0}^{T_4} \left[(H_0 + H_1 t_4) \left\{ (P_0 - P_1 t_4) - (d_0 - d_1 t_4) - \alpha_4 \beta_4 t_4^{\beta_4 - 1} I_M(t_4) \right\} \right] \quad (30)$$

4.4.4 Raw material's net present total cost per unit time

$$TC_W = \left[\frac{MI_W + OC_W + HC_W}{T} \right] \quad (31)$$

$$TC_W = \left[\frac{1}{T} \left[\sum_{t_4=0}^{T_4} \left\{ \begin{array}{l} \left[(P_0 - P_1 t_4) - (d_0 - d_1 t_4) - \alpha_4 \beta_4 t_4^{\beta_4 - 1} I_M(t_4) \right] + \left(W_0 + W_1 t_4 \right) \\ + \left[(H_0 + H_1 t_4) \left\{ (P_0 - P_1 t_4) - (d_0 - d_1 t_4) - \alpha_4 \beta_4 t_4^{\beta_4 - 1} I_M(t_4) \right\} \right] \end{array} \right\} \right] \right] \quad (32)$$

4.5. Distributor center-1 finished goods inventory system:

$$I_{DC_1}(t_5) = (P_0 - P_1 t_5) - (d_0 - d_1 t_5) - \alpha_5 \beta_5 t_5^{\beta_5 - 1} I_{DC_1}(t_5) \; ; 0 \le t_5 \le T_5 \quad (33)$$

4.5.1 Maximum Inventory:-

$$MI_{DC_1} = \sum_{t_5=0}^{T_5} I_{DC_1}(t_5) \quad (34)$$

$$MI_{DC_1} = \sum_{t_5=0}^{T_5} \left[(P_0 - P_1 t_5) - (d_0 - d_1 t_5) - \alpha_5 \beta_5 t_5^{\beta_5 - 1} I_{DC_1}(t_5) \right] \quad (35)$$

4.5.2 Ordering cost

$$OC_{DC_1} = \sum_{t_5=0}^{T_5} \left(C_0 + C_1 t_5 \right) \quad (36)$$

4.5.3 Holding cost

$$HC_{DC_1} = \sum_{t_5=0}^{T_5}\left[(H_0 + H_1 t_5) I_{DC_1}(t_5)\right] \quad (37)$$

$$HC_{DC_1} = \sum_{t_5=0}^{T_5}\left[(H_0 + H_1 t_5)\left\{(P_0 - P_1 t_5) - (d_0 - d_1 t_5) - \alpha_5\beta_5 t_5^{\beta_5 - 1} I_{DC_1}(t_5)\right\}\right] \quad (38)$$

4.5.4 Raw material's net present total cost per unit time

$$TC_{DC_1} = \left[\frac{MI_{DC_1} + OC_{DC_1} + HC_{DC_1}}{T}\right] \quad (39)$$

$$TC_{DC_1} = \left[\frac{1}{T}\left[\sum_{t_5=0}^{T_5}\left\{\begin{array}{l}\left[(P_0 - P_1 t_5) - (d_0 - d_1 t_5) - \alpha_5\beta_5 t_5^{\beta_5 - 1} I_{DC_1}(t_5)\right] + (C_0 + C_1 t_5) \\ + \left[(H_0 + H_1 t_5)\left\{(P_0 - P_1 t_5) - (d_0 - d_1 t_5) - \alpha_5\beta_5 t_5^{\beta_5 - 1} I_{DC_1}(t_5)\right\}\right]\end{array}\right\}\right]\right] \quad (40)$$

4.6. Distributor center-2 finished goods inventory system:

$$I_{DC_2}(t_6) = (P_0 - P_1 t_6) - (d_0 - d_1 t_6) - \alpha_6\beta_6 t_6^{\beta_6 - 1} I_{DC}(t_6)\ ; 0 \le t_6 \le T_6 \quad (41)$$

4.6.1 Maximum Inventory:

$$MI_{DC_2} = \sum_{t_6=0}^{T_6} I_{DC_2}(t_6) \quad (42)$$

$$MI_{DC_2} = \sum_{t_6=0}^{T_6}\left[(P_0 - P_1 t_6) - (d_0 - d_1 t_6) - \alpha_6\beta_6 t_6^{\beta_6 - 1} I_{DC_2}(t_6)\right] \quad (43)$$

4.6.2 Ordering cost

$$OC_{DC_2} = \sum_{t_6=0}^{T_6}(C_0 + C_1 t_6) \quad (44)$$

4.6.3 Holding cost

$$HC_{DC_2} = \sum_{t_6=0}^{T_6}\left[(H_0 + H_1 t_6) I_{DC_2}(t_6)\right] \quad (45)$$

$$HC_{DC_2} = \sum_{t_6=0}^{T_6}\left[(H_0 + H_1 t_6)\left\{(P_0 - P_1 t_6) - (d_0 - d_1 t_6) - \alpha_6\beta_6 t_6^{\beta_6 - 1} I_{DC_2}(t_6)\right\}\right] \quad (46)$$

4.6.4 Raw material's net present total cost per unit time

$$TC_{DC_2} = \left[\frac{MI_{DC_2} + OC_{DC_2} + HC_{DC_2}}{T}\right] \quad (47)$$

$$TC_{DC_2} = \left[\frac{1}{T}\left[\sum_{t_6=0}^{T_6}\left\{\begin{array}{l}\left[(P_0 - P_1 t_6) - (d_0 - d_1 t_6) - \alpha_6\beta_6 t_6^{\beta_6 - 1} I_{DC_2}(t_6)\right] + (C_0 + C_1 t_6) \\ + \left[(H_0 + H_1 t_6)\left\{(P_0 - P_1 t_6) - (d_0 - d_1 t_6) - \alpha_6\beta_6 t_6^{\beta_6 - 1} I_{DC_2}(t_6)\right\}\right]\end{array}\right\}\right]\right] \quad (48)$$

4.7. Distributor center-3 finished goods inventory system:

$$I_{DC_3}(t_7) = (P_0 - P_1 t_7) - (d_0 - d_1 t_7) - \alpha_7 \beta_7 t_7^{\beta_7 - 1} I_{DC}(t_7)\ ; 0 \le t_7 \le T_7 \quad (49)$$

4.7.1 Maximum Inventory:-

$$MI_{DC_3} = \sum_{t_7=0}^{T_7} I_{DC_3}(t_7) \quad (50)$$

$$MI_{DC_3} = \sum_{t_7=0}^{T_7} \left[(P_0 - P_1 t_7) - (d_0 - d_1 t_7) - \alpha_7 \beta_7 t_7^{\beta_7 - 1} I_{DC}(t_7) \right] \quad (51)$$

4.7.2 Ordering cost

$$OC_{DC_3} = \sum_{t_7=0}^{T_7} \left(C_0 + C_1 t_7 \right) \quad (52)$$

4.7.3 Holding cost

$$HC_{DC_3} = \sum_{t_7=0}^{T_7} \left[(H_0 + H_1 t_7) I_{DC_3}(t_7) \right] \quad (53)$$

$$HC_{DC_3} = \sum_{t_7=0}^{T_7} \left[(H_0 + H_1 t_7) \left\{ (P_0 - P_1 t_7) - (d_0 - d_1 t_7) - \alpha_7 \beta_7 t_7^{\beta_7 - 1} I_{DC}(t_7) \right\} \right] \quad (54)$$

4.7.4 Raw material's net present total cost per unit time

$$TC_{DC_3} = \left[\frac{MI_{DC_3} + OC_{DC_3} + HC_{DC_3}}{T} \right] \quad (55)$$

$$TC_{DC_3} = \left[\frac{1}{T} \left[\sum_{t_7=0}^{T_7} \left\{ \begin{array}{l} \left[(P_0 - P_1 t_7) - (d_0 - d_1 t_7) - \alpha_7 \beta_7 t_7^{\beta_7 - 1} I_{DC}(t_7) \right] + \left(C_0 + C_1 t_7 \right) \\ + \left[(H_0 + H_1 t_7) \left\{ (P_0 - P_1 t_7) - (d_0 - d_1 t_7) - \alpha_7 \beta_7 t_7^{\beta_7 - 1} I_{DC}(t_7) \right\} \right] \end{array} \right\} \right] \right] \quad (56)$$

4.8. Retailer's -1 finished goods inventory system:

$$I_{R_1}(t_8) = -(d_0 - d_1 t_8) - \alpha_8 \beta_8 t_8^{\beta_8 - 1} I_R(t_8)\ ; 0 \le t_8 \le T_8 \quad (57)$$

4.8.1 Maximum Inventory:-

$$MI_{R_1} = \sum_{t_8=0}^{T_8} I_{R_1}(t_8) \quad (58)$$

$$MI_{R_1} = \sum_{t_8=0}^{T_8} \left[-(d_0 - d_1 t_8) - \alpha_8 \beta_8 t_8^{\beta_8 - 1} I_R(t_8) \right] \quad (59)$$

4.8.2 Ordering cost

$$OC_{R_1} = \sum_{t_8=0}^{T_8} \left(R_2 + R_3 t_8 \right) \quad (60)$$

4.8.3 Holding cost

$$HC_{R_1} = \sum_{t_8=0}^{T_8} \left[(H_0 + H_1 t_8) I_{R_1}(t_8) \right] \quad (61)$$

$$HC_{R_1} = \sum_{t_8=0}^{T_8} \left[(H_0 + H_1 t_8) \left\{ -(d_0 - d_1 t_8) - \alpha_8 \beta_8 t_8^{\beta_8 - 1} I_R(t_8) \right\} \right] \quad (62)$$

4.8.4 Raw material's net present total cost per unit time

$$TC_{R_1} = \left[\frac{MI_{R_1} + OC_{R_1} + HC_{R_1}}{T} \right] \quad (63)$$

$$TC_{R_1} = \left[\frac{1}{T} \left[\sum_{t_8=0}^{T_8} \left\{ \begin{array}{l} \left[-(d_0 - d_1 t_8) - \alpha_8 \beta_8 t_8^{\beta_8 - 1} I_R(t_8) \right] + (R_2 + R_3 t_8) \\ + \left[(H_0 + H_1 t_8) \left\{ -(d_0 - d_1 t_8) - \alpha_8 \beta_8 t_8^{\beta_8 - 1} I_R(t_8) \right\} \right] \end{array} \right\} \right] \right] \quad (64)$$

4.9. Retailer's-2 finished goods inventory system:

$$I_{R_2}(t_9) = -(d_0 - d_1 t_9) - \alpha_9 \beta_9 t_9^{\beta_9 - 1} I_{R_2}(t_9) \; ; 0 \le t_9 \le T_9 \quad (65)$$

4.9.1 Maximum Inventory:-

$$MI_{R_2} = \sum_{t_9=0}^{T_9} I_{R_2}(t_9) \quad (66)$$

$$MI_{R_2} = \sum_{t_9=0}^{T_9} \left[-(d_0 - d_1 t_9) - \alpha_9 \beta_9 t_9^{\beta_9 - 1} I_{R_2}(t_9) \right] \quad (67)$$

4.9.2 Ordering cost

$$OC_{R_2} = \sum_{t_9=0}^{T_9} (R_4 + R_5 t_9) \quad (68)$$

4.9.3 Holding cost

$$HC_{R_2} = \sum_{t_9=0}^{T_9} \left[(H_0 + H_1 t_9) I_{R_2}(t_9) \right] \quad (69)$$

$$HC_{R_2} = \sum_{t_9=0}^{T_9} \left[(H_0 + H_1 t_9) \left\{ -(d_0 - d_1 t_9) - \alpha_9 \beta_9 t_9^{\beta_9 - 1} I_{R_2}(t_9) \right\} \right] \quad (70)$$

4.9.4 Raw material's net present total cost per unit time

$$TC_{R_2} = \left[\frac{MI_{R_2} + OC_{R_2} + HC_{R_2}}{T} \right] \quad (71)$$

$$TC_{R_2} = \left[\frac{1}{T} \left[\sum_{t_9=0}^{T_9} \left\{ \left[\begin{array}{l} \left[-(d_0 - d_1 t_9) - \alpha_9 \beta_9 t_9^{\beta_9 - 1} I_{R_2}(t_9) \right] + (R_4 + R_5 t_9) \\ +(H_0 + H_1 t_9) \left\{ -(d_0 - d_1 t_9) - \alpha_9 \beta_9 t_9^{\beta_9 - 1} I_{R_2}(t_9) \right\} \end{array} \right] \right\} \right] \right] \quad (72)$$

4.10. Retailer's-3 finished goods inventory system:

$$I_{R_3}(t_{10}) = -(d_0 - d_1 t_{10}) - \alpha_{10} \beta_{10} t_{10}^{\beta_{10} - 1} I_R(t_{10}) \; ; 0 \le t_{10} \le T_{10} \quad (73)$$

4.10.1 Maximum Inventory:-

$$MI_{R_3} = \sum_{t_{10}=0}^{T_{10}} I_{R_3}(t_{10}) \quad (74)$$

$$MI_{R_3} = \sum_{t_{10}=0}^{T_{10}} \left[-(d_0 - d_1 t_{10}) - \alpha_{10}\beta_{10} t_{10}^{\beta_{10}-1} I_R(t_{10}) \right] \quad (75)$$

4.10.2 Ordering cost

$$OC_{R_3} = \sum_{t_{10}=0}^{T_{10}} \left(R_4 + R_5 t_{10} \right) \quad (76)$$

4.10.3 Holding cost

$$HC_{R_3} = \sum_{t_{10}=0}^{T_{10}} \left[(H_0 + H_1 t_{10}) I_{R_3}(t_{10}) \right] \quad (77)$$

$$HC_{R_3} = \sum_{t_{10}=0}^{T_{10}} \left[(H_0 + H_1 t_{10}) \left\{ -(d_0 - d_1 t_{10}) - \alpha_{10}\beta_{10} t_{10}^{\beta_{10}-1} I_R(t_{10}) \right\} \right] \quad (78)$$

4.10.4 Raw material's net present total cost per unit time

$$TC_{R_3} = \left[\frac{MI_{R_3} + OC_{R_3} + HC_{R_3}}{T} \right] \quad (79)$$

$$TC_{R_3} = \left[\frac{1}{T} \left[\sum_{t_{10}=0}^{T_{10}} \left\{ \begin{array}{l} \left[-(d_0 - d_1 t_{10}) - \alpha_{10}\beta_{10} t_{10}^{\beta_{10}-1} I_R(t_{10}) \right] + \left(R_4 + R_5 t_{10} \right) \\ + \left[(H_0 + H_1 t_{10}) \left\{ -(d_0 - d_1 t_{10}) - \alpha_{10}\beta_{10} t_{10}^{\beta_{10}-1} I_R(t_{10}) \right\} \right] \end{array} \right\} \right] \right] \quad (80)$$

$$TC = \left[\frac{TC_{RM} + TC_S + TC_M + TC_W + TC_{DC_1} + TC_{DC_2} + TC_{DC_3} + TC_{R_1} + TC_{R_2} + TC_{R_3}}{T} \right] \quad (81)$$

$$
TC = \left[\frac{1}{T} \left[\begin{aligned}
&\left[\sum_{t_1=0}^{T_1} \left\{ \begin{aligned} &\left[\theta_1\theta_2 t_1^{\theta_2-1} I_{RM}(t_1) - \alpha_1\beta_1 t_1^{\beta_1-1} I_{RM}(t_1)\right] + \left(R_0 + R_1 t_1\right) \\ &+\left[(H_0 + H_1 t_1)\{\theta_1\theta_2 t_1^{\theta_2-1} I_{RM}(t_1) - \alpha_1\beta_1 t_1^{\beta_1-1} I_{RM}(t_1)\}\right] \end{aligned} \right\} \right] \\
&+\left[\sum_{t_2=0}^{T_2} \left\{ \begin{aligned} &\left[(d_0 - d_1 t_2) - \alpha_2\beta_2 t_2^{\beta_2-1} I_S(t_2)\right] + \left(S_0 + S_1 t_2\right) \\ &+\left[(H_0 + H_1 t_2)\left\{(d_0 - d_1 t_2) - \alpha_2\beta_2 t_2^{\beta_2-1} I_S(t_2)\right\}\right] \end{aligned} \right\} \right] \\
&+\left[\sum_{t_3=0}^{T_3} \left\{ \begin{aligned} &\left[(P_0 - P_1 t_3) - (d_0 - d_1 t_3) - \alpha_3\beta_3 t_3^{\beta_3-1} I_M(t_3)\right] + \left(M_0 + M_1 t_3\right) \\ &+\left[(H_0 + H_1 t_3)\left\{(P_0 - P_1 t_3) - (d_0 - d_1 t_3) - \alpha_3\beta_3 t_3^{\beta_3-1} I_M(t_3)\right\}\right] \end{aligned} \right\} \right] \\
&+\left[\sum_{t_4=0}^{T_4} \left\{ \begin{aligned} &\left[(P_0 - P_1 t_4) - (d_0 - d_1 t_4) - \alpha_4\beta_4 t_4^{\beta_4-1} I_M(t_4)\right] + \left(W_0 + W_1 t_4\right) \\ &+\left[(H_0 + H_1 t_4)\left\{(P_0 - P_1 t_4) - (d_0 - d_1 t_4) - \alpha_4\beta_4 t_4^{\beta_4-1} I_M(t_4)\right\}\right] \end{aligned} \right\} \right] \\
&+\left[\sum_{t_5=0}^{T_5} \left\{ \begin{aligned} &\left[(P_0 - P_1 t_5) - (d_0 - d_1 t_5) - \alpha_5\beta_5 t_5^{\beta_5-1} I_{DC_1}(t_5)\right] + \left(C_0 + C_1 t_5\right) \\ &+\left[(H_0 + H_1 t_5)\left\{(P_0 - P_1 t_5) - (d_0 - d_1 t_5) - \alpha_5\beta_5 t_5^{\beta_5-1} I_{DC_1}(t_5)\right\}\right] \end{aligned} \right\} \right] \\
&+\left[\sum_{t_6=0}^{T_6} \left\{ \begin{aligned} &\left[(P_0 - P_1 t_6) - (d_0 - d_1 t_6) - \alpha_6\beta_6 t_6^{\beta_6-1} I_{DC_2}(t_6)\right] + \left(C_0 + C_1 t_6\right) \\ &+\left[(H_0 + H_1 t_6)\left\{(P_0 - P_1 t_6) - (d_0 - d_1 t_6) - \alpha_6\beta_6 t_6^{\beta_6-1} I_{DC_2}(t_6)\right\}\right] \end{aligned} \right\} \right] \\
&+\left[\sum_{t_7=0}^{T_7} \left\{ \begin{aligned} &\left[(P_0 - P_1 t_7) - (d_0 - d_1 t_7) - \alpha_7\beta_7 t_7^{\beta_7-1} I_{DC}(t_7)\right] + \left(C_0 + C_1 t_7\right) \\ &+\left[(H_0 + H_1 t_7)\left\{(P_0 - P_1 t_7) - (d_0 - d_1 t_7) - \alpha_7\beta_7 t_7^{\beta_7-1} I_{DC}(t_7)\right\}\right] \end{aligned} \right\} \right] \\
&+\left[\sum_{t_8=0}^{T_8} \left\{ \begin{aligned} &\left[-(d_0 - d_1 t_8) - \alpha_8\beta_8 t_8^{\beta_8-1} I_R(t_8)\right] + \left(R_2 + R_3 t_8\right) \\ &+\left[(H_0 + H_1 t_8)\left\{-(d_0 - d_1 t_8) - \alpha_8\beta_8 t_8^{\beta_8-1} I_R(t_8)\right\}\right] \end{aligned} \right\} \right] \\
&+\left[\sum_{t_9=0}^{T_9} \left\{ \left[\begin{aligned} &\left[-(d_0 - d_1 t_9) - \alpha_9\beta_9 t_9^{\beta_9-1} I_{R_2}(t_9)\right] + \left(R_4 + R_5 t_9\right) \\ &+(H_0 + H_1 t_9)\left\{-(d_0 - d_1 t_9) - \alpha_9\beta_9 t_9^{\beta_9-1} I_{R_2}(t_9)\right\} \end{aligned} \right] \right\} \right] \\
&+\left[\sum_{t_{10}=0}^{T_{10}} \left\{ \begin{aligned} &\left[-(d_0 - d_1 t_{10}) - \alpha_{10}\beta_{10} t_{10}^{\beta_{10}-1} I_R(t_{10})\right] + \left(R_4 + R_5 t_{10}\right) \\ &+\left[(H_0 + H_1 t_{10})\left\{-(d_0 - d_1 t_{10}) - \alpha_{10}\beta_{10} t_{10}^{\beta_{10}-1} I_R(t_{10})\right\}\right] \end{aligned} \right\} \right]
\end{aligned} \right] \right] \quad (82)
$$

5. Genetic Algorithm Model in Supply Chain Inventory control

Which depicts the steps applied for the optimization analysis. Initially, the amount of stock levels that are in excess and the amount of stocks in shortage in the different supply chain contributors are represented by zero or non-zero values. Zero refers that the contributor needs no inventory control while the non-zero data requires the inventory control. The non-zero data states both the excess amount of stocks as well as shortage amount. The excess amount is given as positive value and the shortage amount is mentioned as negative value.

The first process needs to do is the clustering that clusters the stock levels that are either in excess or in shortage and the stock levels that are neither in excess nor in shortage separately. This is done simply by clustering the zero and non-zero values. For this purpose we are using, the efficient Economic Load Dispatch algorithm.

After the process of Economic Load Dispatch method using Genetic Algorithm is performed, the work starts its proceedings on Genetic algorithm, the heart of our work. For the Economic Load Dispatch using Genetic Algorithm, instead of generating an initial population having chromosomes of random value, a random chromosome is generated in each time of the iteration for further operation.

Compute $TC_n\ (x)$ for given x by Genetic Algorithm

For each given state u in order compute the optimal cost with respect to it, we must solve the following optimization problem

$$TC_n\ (x) = \min_{y \geq x} T_n\ (x) - A_n\ .x,$$
$$x \in \Pi_n, y \in \Xi_n$$

Now, we give a genetic algorithm procedure for solving the above optimization problem

Genetic Algorithm Procedure for optimal cost:

Step 1. Initialize pop size chromosomes randomly.

Step 2. Update the chromosomes by crossover and mutation operations.

Step 3. Calculate the objective values for all chromosomes.

Step 4. Compute the fitness of each chromosome according to the objective values.

Step 5. Select the chromosomes by spinning the roulette wheel.

Step 6. Repeat the second to fifth steps for a given number of cycles.

Step 7. Report the best chromosomes as the optimal cost for the given state u .

6. Multi-Objective Particle Swarm Optimization Algorithm

Step 1: P: =0

Step 2: $\{M_x, N_x, U_x\ , V_x\}_{x=1}^{X}$:= initialize()

Step 3: for a:= 1: U

Step 4: for b:= 1: X

Step 5: for r:= 1: R

Step 6: $n_{xc}^{(a+1)} = yn_{xc}^{a} + c_1 d_1 [V_{xc} - m_{xc}^{a}] + c_2 d_2\ [U_{xc} - m_{xc}^{a}]$

Step 7: $M_x^{a+1} = M_x^{a} + mN_x^{a} + \in^{a}$

Step 8: end

Step 9: M_x:= enforce Constraints(X)

Step 10: Y_x := f(M_x)

Step 11: if $M_x \npreceq$e ∀ e ∈ P

Step 12: P:= {e ∈P/ e$\nprec M_x$ }

Step 13: P:= P∪M_x

Step 14: end

Step 15: end

Step 16: if $M_x \preceq V_x$ ∨ ($X M_x \nprec V_x$ ∧ $V_x \nprec M_x$)

Step 17: V_x := M_x

Step 18: end

Step 19: U_x := selectGuide(X , A)

Step 20: end

7. Experimental Results

Let for the production rate $(P_0 - P_1 t_5)$, P_0=200, P_1= 100 and for the demand rate $(d_0 - d_1 t_i)$, $d_0 = 100$ $d_1 = 150$ ameliorating cost $\theta_1 = 300$, ameliorating rate $\theta_2 = 200$,

$$(\text{Ordering cost is; } RM = 325, S = 300, M = 275, W = 250, D_1 = 225, D_2 = 225, \\ D_3 = 225, R_1 = 200, R_2 = 200, R_3 = 200)$$

$$\begin{bmatrix} \text{Holding cost is}: (H_0 + H_1 t_i), RW = 2, S = 2.5, M = 3, W = 3.5, D_1 = 4, D_2 = 4, \\ D_3 = 4, R_1 = 4.5, R_2 = 4.5, R_3 = 4.5 \end{bmatrix}$$

$$(\text{Deterioration cost is}; -\alpha_1 = 1.08, \alpha_2 = 1.07, \alpha_3 = 1.06, \alpha_4 = 1.05, \alpha_5 = 1.04, \alpha_6 = 1.04, \\ \alpha_7 = 1.04, \alpha_8 = 1.03, \alpha_9 = 1.03, \alpha_{10} = 1.03)$$

$$(\text{Deterioration cost is}; -\beta_1 = 3.06, \beta_2 = 3.05, \beta_3 = 3.04, \beta_4 = 3.03, \beta_5 = 3.02, \beta_6 = 3.02, \\ \beta_7 = 3.02, \beta_8 = 3.01, \beta_9 = 3.01, \beta_{10} = 3.01)$$

The aim of this section is to understand the application of both Binary GA and Continuous GA for economic dispatching of generating power in a power system satisfying the power balance constraint for system demand and total generating power as well as the generating power constraints for all units. GA: real coded, population=50, generations=350, crossover probability=5.5, mutation probability=0.8, ELD: Units data for eight generators, Total demand = 350

Table:-1 Supply chain inventory model optimal solution

K	1	2	3	4	5	6
T_1	1.22	1.24	1.26	1.26	1.28	1.30
T_2	1.32	1.34	1.36	1.38	1.40	1.42
T_3	2.20	2.25	2.30	2.35	2.40	2.45
T_4	3.10	3.15	3.20	3.25	3.30	3.35
T_5	1.15	1.20	1.25	1.30	1.35	1.40
T_6	1.15	1.20	1.25	1.30	1.35	1.40
T_7	1.15	1.20	1.25	1.30	1.35	1.40
T_8	1.20	1.30	1.40	1.50	1.60	1.70
T_9	1.20	1.30	1.40	1.50	1.60	1.70
T_{10}	1.20	1.30	1.40	1.50	1.60	1.70
TC_{RM}	**333.41**	335.42	337.21	345.24	355.15	357.46
TC_S	420.10	**415.05**	425.12	430.15	435.25	440.14
TC_M	520.05	531.45	525.58	**519.15**	530.15	535.25
TC_W	615.00	620.15	635.75	630.15	640.15	**610.15**
TC_{DC_1}	620.05	622.32	**619.12**	624.12	626.45	628.15
TC_{DC_2}	620.05	622.32	**619.12**	624.12	626.45	628.15
TC_{DC_3}	620.05	622.32	**619.12**	624.12	626.45	628.15
TC_{R_1}	320.10	322.05	324.10	**315.16**	325.15	326.20
TC_{R_2}	320.10	322.05	324.10	**315.16**	325.15	326.20
TC_{R_3}	320.10	322.05	324.10	**315.16**	325.15	326.20
TC	2225.14	2235.25	**2200.35**	2240.14	2245.12	2250.25

Genetic algorithm

The aim of this section is to understand the application of both Binary GA and Continuous GA for economic dispatching of generating power in a power system satisfying the power balance constraint for system demand and total generating power as well as the generating power constraints for all units. GA: real coded, population=25, generations=250, crossover probability=4.5, mutation probability=1.2., ELD: Units data for eight generators, Total demand = 250.

The optimization of inventory control in supply chain management based on Economic Load Dispatch using genetic algorithm is analyzed with the help of MATLAB. The stock levels for the three different members of the supply chain, Raw material, Storage, Manufacture, warehouse, distribution centers, Retailer's are generated using the MATLAB script and this generated data set is used for evaluating the performance of the genetic algorithm. Some sample set of data used in the implementation is given in table 2. Some 7 sets of data are given in the table 2 and these are assumed as the records of the past period.

Table:-2 Genetic algorithm (GA) model optimal solution

P	WW	GA			
	OPT	BEST	MAX	AVG	STD
1	2175.50	2171.50	2165.50	1175.50	2075.50
2	2177.00	2170.00	2167.00	1177.00	2077.00
3	2251.00	2252.00	2241.00	1251.00	2151.00
4	2339.00	2338.00	2329.00	1339.00	2239.00
5	2411.25	2410.25	2401.25	1411.25	2311.25
6	2524.50	2524.50	2514.50	1524.50	2424.50
7	2634.50	2633.50	2624.50	1634.50	2534.50

Particle Swarm Optimization (PSO)
Population=290
Generations=700
Cognitive learning factor=24
Cooperative factor=24
Social learning factor=20.10
Inertial constant=20.10 and number of neighbors=210.
The optimization of inventory control in supply chain management based on Particle Swarm Optimization (PSO) Particle Swarm Optimization (PSO) is analyzed with the help of MATLAB. The stock levels for the three different members of the supply chain, Raw material, Storage, Manufacture, warehouse, distribution centers, Retailer's are generated using the MATLAB script and this generated data set is used for evaluating the performance of the Particle Swarm Optimization (PSO). Some sample set of data used in the implementation is given in table 3. Some 7 sets of data are given in the table 3 and these are assumed as the records of the past period.

Table:-3 Particle Swarm Optimization (PSO) model optimal solution

P	WW	PSO			
	OPT	BEST	MAX	AVG	STD
1	3115.50	3015.50	3105.50	2115.50	3104.50
2	3477.00	3377.00	3466.00	2477.00	3476.00
3	3551.00	3451.00	3541.00	2551.00	3550.00
4	3639.00	3539.00	3629.00	2639.00	3638.00
5	3711.25	3611.25	3701.25	2711.25	3710.25
6	3824.50	3724.50	3814.50	2824.50	3823.50
7	3934.50	3834.50	3924.50	2934.50	3933.50

8. CONCLUSION

In this paper an integrated production supply chain inventory model with linear production and demand rate has been developed for deteriorating item and economic load dispatch using Genetic algorithm and Particle Swarm optimization is a significant component of supply chain management. In this model the deterioration, the multiple deliveries and the time discounting are considered from the perspective of six stage 10 Member Supply Chain supply chain, Raw material, Storage, Manufacture, warehouse, three distribution centers as well as three Retailer's and economic load dispatch using Genetic algorithm and Particle Swarm optimization. This work can further be extended for six stage 10 Member Supply Chain supply chain, Raw material, multi-Storage, multi-Manufacture, multi-warehouse, multi-distribution centers-1, multi-distribution centers-2, multi-distribution centers-3, Retailer's-1, Retailer's-2, Retailer's-3, economic load dispatch using Genetic algorithm and Particle Swarm optimization and including distributors in the supply chain inventory system. The proposed method was implemented and its performance was evaluated using MATLAB.

References

[1]. Yimer, A.D. and Demirli, K. (2010) A genetic approach to two-phase optimization of dynamic supply chain scheduling Computers & Industrial Engineering, Volume 58, Issue 3, Pages 411-422.

[2]. Taleizadeh, A.A, Niaki, S.T.A. and Barzinpour, F. (2011) Multiple-buyer multiple-vendor multi-product multi-constraint supply chain problem with stochastic demand and variable lead-time: A harmony search algorithm Applied Mathematics and Computation, Volume 217, Issue 22, Pages 9234-9253.

[3]. Che, Z.H. and Chiang, C.J. (2010) A modified Pareto genetic algorithm for multi-objective build-to-order supply chain planning with product assembly Advances in Engineering Software, Volume 41, Issues 7–8, Pages 1011-1022.

[4]. Changdar, C., Mahapatra, G.S., and Pal, R.K. (2015) An improved genetic algorithm based approach to solve constrained knapsack problem in fuzzy environment Expert Systems with Applications, Volume 42, Issue 4, Pages 2276-2286.

[5]. Kannan, G., Sasikumar, P. and Devika, K. (2010) A genetic algorithm approach for solving a closed loop supply chain model: A case of battery recycling Applied Mathematical Modelling, Volume 34, Issue 3, Pages 655-670.

[6]. Zhang, H., Deng, Y., Chan, F.T.S. and Zhang, X. (2013) A modified multi-criterion optimization genetic algorithm for order distribution in collaborative supply chain Applied Mathematical Modelling, Volume 37, Issues 14–15, Pages 7855-7864.

[7]. Dey, J.K., Mondal, S.K. and Maiti, M. (2008)Two storage inventory problem with dynamic demand and interval valued lead-time over finite time horizon under inflation and time-value of money European Journal of Operational Research, Volume 185, Issue 1, Pages 170-194.

[8]. Jiang, Y., Chen, M. and Zhou, D. (2015) Joint optimization of preventive maintenance and inventory policies for multi-unit systems subject to deteriorating spare part inventory Journal of Manufacturing Systems, Volume 35, Pages 191-205.

[9]. Sourirajan, K., Ozsen, L. and Uzsoy, R. (2009) A genetic algorithm for a single product network design model with lead time and safety stock considerations European Journal of Operational Research, Volume 197, Issue 2, Pages 599-608.

[10]. Sarrafha, K., Rahmati, S.H.A., Niaki, S.T.A. and Zaretalab, A. (2015) A bi-objective integrated procurement, production, and distribution problem of a multi-echelon supply chain network design: A new tuned MOEA Computers & Operations Research, Volume 54, Pages 35-51.
[11]. Wang, K.J., Makond, B. and Liu, S.Y. (2011) Location and allocation decisions in a two-echelon supply chain with stochastic demand – A genetic-algorithm based solution Expert Systems with Applications, Volume 38, Issue 5, Pages 6125-6131.
[12]. Jawahar, N. and Balaji, A.N. (2009) A genetic algorithm for the two-stage supply chain distribution problem associated with a fixed charge European Journal of Operational Research, Volume 194, Issue 2, Pages 496-537.
[13]. Jawahar, N. and Balaji, A.N. (2012) A genetic algorithm based heuristic to the multi-period fixed charge distribution problem Applied Soft Computing, Volume 12, Issue 2, Pages 682-699.
[14]. Ramkumar, N., Subramanian, P., Narendran, T.T. and Ganesh, K. (2011) Erratum to "A genetic algorithm approach for solving a closed loop supply chain model: A case of battery recycling" Applied Mathematical Modelling, Volume 35, Issue 12, Pages 5921-5932.
[15]. Narmadha, S., Selladurai, V. and Sathish, G. (2010) Multi-Product Inventory Optimization using Uniform Crossover Genetic Algorithm International Journal of Computer Science and Information Security,Vol. 7, No. 1.
[16]. Partha Guchhait, Manas Kumar Maiti, Manoranjan Maiti (2010) Multi-item inventory model of breakable items with stock-dependent demand under stock and time dependent breakability rate Computers & Industrial Engineering, Volume 59, Issue 4, Pages 911-920.
[17]. Priya, P. and Iyakutti , K. Web based Multi Product Inventory Optimization using Genetic Algorithm International Journal of Computer Applications (0975 – 8887) Volume 25– No.8.
[18]. Radhakrishnan, P., Prasad, V.M. and Gopalan, M.R. (2009) Inventory Optimization in Supply Chain Management using Genetic Algorithm International Journal of Computer Science and Network Security, VOL.9 No.1.
[19]. Sasan Khalifehzadeh, Mehdi Seifbarghy, Bahman Naderi (2015) A four-echelon supply chain network design with shortage: Mathematical modeling and solution methods Journal of Manufacturing Systems, Volume 35, Pages 164-175.
[20]. Pasandideh, S.H.R., Niaki, S.T.A and Yeganeh, J.A (2010) A parameter-tuned genetic algorithm for multi-product economic production quantity model with space constraint, discrete delivery orders and shortages Advances in Engineering Software, Volume 41, Issue 2, Pages 306-314.
[21]. Li, S.H.A., Tserng, H.P., Yin, Y.L.S. and Hsu, C.W (2010) A production modeling with genetic algorithms for a stationary pre-cast supply chain Expert Systems with Applications, Volume 37, Issue 12, Pages 8406-8416.
[22]. Singh, S.R. and Kumar, T (2011). Inventory Optimization in Efficient Supply Chain Management International Journal of Computer Applications in Engineering Sciences Vol. 1 Issue 4.
[23]. Thakur, L and Desai, A.A. Inventory Analysis Using Genetic Algorithm In Supply Chain Management International Journal of Engineering Research & Technology (IJERT) Vol. 2 Issue 7.

[24]. Wong, W.K., Mok, P.Y. and Leung, S.Y.S. (2013) 8 - Optimizing apparel production systems using genetic algorithms Optimizing Decision Making in the Apparel Supply Chain Using Artificial Intelligence (AI), Pages 153-169.

[25]. Yeh, W.C. and Chuang, M.C. (2011) Using multi-objective genetic algorithm for partner selection in green supply chain problems Expert Systems with Applications, Volume 38, Issue 4, Pages 4244-4253.

[26]. Ye, Z., Li, Z. and Xie, M. (2010) Some improvements on adaptive genetic algorithms for reliability-related applications Reliability Engineering & System Safety, Volume 95, Issue 2, February 2010, Pages 120-126.

[27]. Yadav, A.S. (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.

[28]. 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.

[29]. 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.

[30]. Yadav, A.S., Swami, A., Kher, G. and Kumar, S. (2017) Supply Chain Inventory Model for Two Warehouses with Soft Computing Optimization International Journal Of Applied Business And Economic Research Volume 15 No 4.

[31]. 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.

[32]. 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 GA And PSO Asian Journal Of Mathematics And Computer Research volume 16 No.4.

[33]. 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.

[34]. 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.

[35]. Yadav, A.S., Tyagi, B., Sharma, 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.

[36]. 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.

[37]. Singh, R.K., Yadav, A.S. and Swami, A. (2016) A Two-Warehouse Model for Deteriorating Items with Holding Cost under Particle Swarm Optimization International Journal of Advanced Engineering, Management and Science (IJAEMS) Volume -2, Issue-6.

[38]. Singh, R.K., Yadav, A.S. and Swami, A. (2016) A Two-Warehouse Model for Deteriorating Items with Holding Cost under Inflation and Soft Computing Techniques International Journal of Advanced Engineering, Management and Science (IJAEMS) Volume -2, Issue-6.
[39]. Sharma, S., Yadav, A.S. and Swami, A. (2016) An Optimal Ordering Policy For Non-Instantaneous Deteriorating Items With Conditionally Permissible Delay In Payment Under Two Storage Management International Journal of Computer Applications Volume 140 –No.4.
[40]. Yadav, A.S., Sharma, 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.