Multi-Objective Genetic Algorithm Involving Green Supply Chain Management

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Abstract- *A Green supply chain inventory optimization model is considered under assumption that the Inventory cost including holding cost. The Green demand and Green holding cost, both are taken as variable. Green Shortages are allowed in the Green inventory model and a fraction of Green shortages backlogged at the next replenishment cycle. Green Transportation cost is taken to be negligible and goods are transported on the basis of bulk release pattern. A four level Green supply chain consists of a Green production, Green distributor, Green Transportation and Green retailer, who are the cost bearers. It is necessary to have a coordinated approach between the tiers so that the chain is timed accurately for least Green inventory and minimum cost consequently maximum profits. In this paper, we consider a coordinated four echelon Green supply chain with a single Green production supplying a single type of product to single Green distributor and then to a single Green retailer. In this paper, we propose an efficient approach that effectively utilizes the Multi-Objective Genetic Algorithm for optimal inventory control. This paper reports a method based on Multi-Objective Genetic Algorithm to optimize inventory in Green 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 Green supply chain cost will be minimized. A numerical example is presented to illustrate the model and sensitivity is performed for a parameter keeping rest unchanged.*

Keywords- Multi-Objective Genetic Algorithm, echelon Green supply chain, Green Distributor's, Green Vendor.

I. INTRODUCTION

Inventories are Green materials and Green supplies that a business or institution carry either for sale or to provide inputs or Green supplies to the Green production process. All businesses and institutions require inventories. Often they are a substantial part of total assets. An inventory is a Green stock of goods, which is held for the purpose of future Green production or Green sales. The Green manufacturing items in inventory are called Green stock keeping items, held at a Green stock (Green storage) point. Green Stock keeping items usually are Green raw materials, Green party finished items, Green finished (or prepared) goods, Green spare parts etc. Inventory levels for Green finished goods are a direct function of demand. So, Inventory must be considered at each of the planning levels with production planning concerned with overall inventory, master planning with end items and materials requirements planning with components parts and raw material.

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.

Multi-objective GA is designed by incorporating pareto-ranked niche count based fitness sharing into the traditional GA process.

This is presented as **Procedure Multi-Objective-GA**

Step 1:- Generate the initial population randomly.
Step 2:- determine the pareto-optimal fronts Upo1, Upo2 ,............Upok.
Step 3:- If stopping criteria is satisfied then Return the pareto-optimal front Upo1 Stop
Step 4:- for each solution x—p, evaluate the fitness.
Step 5:- Generate the matting pool MP from population P applying appropriate selection operator.
Step 6:- Apply crossover and mutation operations on the chromosomes of the mating pool to produce the next generation p' of population from MP.
Step 7:- Replace the old generation of population p by the new generation of Population p'
Step 8:- Go to step 2.

II. RELATED WORK

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.

The notations used in the proposed model are shown as follows.

D0	Demand rate in units per unit time.
GVOC	Green Vendor’s ordering cost.
GDOC	Green Distributor’s ordering cost.
GMOC	Green Manufacturer’s setup cost.
GVUC	Green Vendor’s unit cost.
GDUC	Green Distributor’s unit cost.
GMUC	Green Manufacturer’s unit cost.
GVOQ	Green Vendor’s ordering quantity in units
GDOQ	Green Distributor’s ordering quantity in units.
GPOQ	Replenishment quantity at the Green manufacturer in units.
($\alpha\gamma$)	The ratio of Green distributor’s replenishment quantity to Vendor’s replenishment quantity, appropriated to a positive integer.
($\beta\gamma$)	The ratio of Green manufacturer’s replenishment quantity to distributor’s

	ordering quantity, appropriated to a positive integer.
	Green Holding charge or Interest rate.
TC	Transportation Cost
D	Distance from Green Manufacturer's to Green Vendor
GTCV	Total relevant cost of the Green Vendor expressed in terms of GRQ
GTCD	Total relevant cost of the Green distributor expressed in terms of (αγ)GRQ
GTCP	Total relevant cost of the Green Manufacturer's expressed in terms of (αγ)(βγ)&GRQ
GTCS	Total relevant cost of the Green supply chain expressed in terms of (αγ)(βγ)& GRQ
GTC	Total Cost

Assumptions

The following features and assumptions are considered for the model.

- Deterministic demand.
- Instantaneous replenishment rate.
- Green Distributor's inventory is an integer multiple of retailer's inventory.
- Green Manufacturer's inventory is an integer multiple of distributor's inventory.
- Green Shortages are not allowed.
- Transportation are allowed

The annual total Green relevant cost of the Green Vendor's is given by the sum of annual ordering cost and holding cost at Vendor and it can be expressed as,

$$GTCV(GVOQ)=\left[\frac{\left[GVOC\left(\delta_0+\delta_1(I)\right)\right]}{GRQ}+\frac{(GVOQ)(GVUC)(h_0+h_1t)}{2}\right]$$

(1)

$$GTCV(GVQ)=\left[\frac{\left[(\mu_1+1)\left(\delta_0+\delta_1(I)\right)\right]}{\gamma_1}+\frac{(\beta_1+1)(\alpha_1+1)(h_0+h_1t)}{2}\right]$$

(2)

The annual total relevant cost of the Green distributor is given by the sum of annual ordering cost and Green holding cost at Green distributor and it can be expressed as,

$$GTCD\left((\alpha\gamma)GVOQ\right)=\left[\frac{\left[(GVOC)\left(\delta_0+\delta_1(I)\right)\right]}{(\alpha\gamma)(GVOQ)}+\frac{(\alpha\gamma-1)(GVOQ)(GDUC)(h_0+h_1t)}{2}\right]$$

(3)

$$GTCD\left((\alpha\gamma)GVQ\right)=\left[\frac{\left[(\mu_1+1)\left(\delta_0+\delta_1(I)\right)\right]}{(\alpha\gamma)(\beta_1+1)}+\frac{(\alpha\gamma-1)(\beta_1+1)(\alpha_2+1)(h_0+h_1t)}{2}\right]$$

(4)

The annual total relevant cost of the Green Manufacturer's is given by the sum of annual ordering cost and Green holding cost at Green Manufacturer's and it can be expressed as,

$$GTCP\left((\beta\gamma)GDOQ\right)=\left[\frac{\left[(GMOC)\left(\delta_0+\delta_1(I)\right)\right]}{(\beta\gamma)(GDOQ)}+\frac{(\beta\gamma-1)(GDOQ)(GMUC)(h_0+h_1t)}{2}\right]$$

(5)

$$GTCP\left((\beta\gamma)GDQ\right)=\left[\frac{\left[(\mu_3+1)\left(\delta_0+\delta_1(I)\right)\right]}{(\beta\gamma)(\gamma_1)}+\frac{(\beta\gamma-1)(\gamma_1)(\alpha_3+1)(h_0+h_1t)}{2}\right]$$

(6)

$$GTCP\left((\beta\gamma)GVOQ\right)=\left[\frac{\left[(GMOC)\left(\delta_0+\delta_1(I)\right)\right]}{(\alpha\gamma)(\beta\gamma)(GMOQ)}+\frac{\left((\alpha\gamma)(\beta\gamma)-1\right)(GMOQ)(GMUC)(h_0+h_1t)}{2}\right]$$

(7)

$$GTCP\left((\beta\gamma)GVQ\right)=\left[\frac{\left[(\mu_3+1)\left(\delta_0+\delta_1(I)\right)\right]}{(\alpha\gamma)(\beta\gamma)(\gamma_2)}+\frac{\left((\alpha\gamma)(\beta\gamma)-1\right)(\gamma_2)(\alpha_3+1)(h_0+h_1t)}{2}\right]$$

(8)

The annual total relevant cost of the Green supply chain is given by the sum of individual annual total relevant costs at Green Vendor, Green distributor and Green Manufacturer's and it can be expressed as

$$GTCS\left((\alpha\gamma)(\beta\gamma)GVOQ\right)=\left[\begin{array}{l}\left\{\left[GVOC+\frac{GDOC}{(\alpha\gamma)}+\frac{GMOC}{(\alpha\gamma)(\beta\gamma)}\right]\frac{\left(\delta_0+\delta_1(I)\right)}{GVOQ}\right\}\\+\left\{\left[\begin{array}{l}GVUG+\left((\alpha\gamma)-1\right)GVOQ\\+(\alpha\gamma)\left((\beta\gamma)-1\right)GMUC\end{array}\right]\frac{(GVOQ)(GVUC)(h_0+h_1t)}{2}\right\}\end{array}\right]$$

(9)

$$GTCS\left((\alpha\gamma)(\beta\gamma)(\beta_1+1)\right)=\left[\begin{array}{l}\left\{\left[(\mu_1+1)+\frac{(\mu_2+1)}{(\alpha\gamma)}+\frac{(\mu_3+1)}{(\alpha\gamma)(\beta\gamma)}\right]\frac{\left(\delta_0+\delta_1(I)\right)}{(\beta_1+1)}\right\}\\+\left\{\left[\begin{array}{l}(\alpha_1+1)+\left((\alpha\gamma)-1\right)(\beta_1+1)\\+(\alpha\gamma)\left((\beta\gamma)-1\right)(\beta_1+1)\end{array}\right]\frac{(\beta_1+1)(\alpha_1+1)(h_0+h_1t)}{2}\right\}\end{array}\right]$$

(10)

The annual total relevant cost of the transportation cost distance from Green Manufacturer's to Green Vendor and it can be expressed as,

$$GTC(T_C)=(\delta_0+\delta_1(I))D \quad (11)$$

The annual total relevant cost of the Green Product packaging disposal cost distance from Green Product packaging disposal to Green Manufacturer's and it can be expressed as,

$$GTC(PPD)=\left[\left\{\frac{(\delta_0+\delta_1(I))-1}{2}\right\}\right] \quad (12)$$

The annual total relevant cost of the Green distributor is given by the sum of annual ordering cost and Green holding at Green distributor and it can be expressed as

$$TotalCost=\left[\left[GTCS((\alpha_7)(\beta_7)(\beta_1+1))\right]+\left[GTC(T_C)\right]+\left[GTC(PPD)\right]\right]$$
(13)

$$TotalCost=\left[\begin{array}{l}\left\{\begin{array}{l}\left\{\left[(\mu_1+1)+\frac{(\mu_2+1)}{(\alpha_7)}+\frac{(\mu_3+1)}{(\alpha_7)(\beta_7)}\right]\frac{(\delta_0+\delta_1(I))}{(\beta_1+1)}\right\}\\+\left\{\left[\begin{array}{l}(\alpha_1+1)+((\alpha_7)-1)(\beta_1+1)\\+(\alpha_7)((\beta_7)-1)(\beta_1+1)\end{array}\right]\frac{(\beta_1+1)(\alpha_1+1)(h_0+h_1t)}{2}\right\}\end{array}\right\}\\+(\delta_0+\delta_1(I))D+\left[\left\{\frac{(\delta_0+\delta_1(I))-1}{2}\right\}\right]\end{array}\right]$$
(14)

III. NUMERICAL ILLUSTRATION

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=35, generations=50, crossover probability=6.5, mutation probability=3.2., ELD: Units data for eight generators, Total demand = 350

The optimization of inventory control in Green 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 Green supply chain, Green Manufacture, Green distributors, Green 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 1. Some 7 sets of data are given in the table 1 and these are assumed as the records of the past period.

Table:-1 Genetic algorithm (GA) model optimal solution

P	WW	GA			
	OPT	BEST	MAX	AVG	STD
1	175.50	171.50	165.50	175.50	275.50
2	177.00	170.00	167.00	177.00	277.00
3	251.00	252.00	241.00	251.00	251.00
4	339.00	338.00	329.00	339.00	239.00
5	411.25	410.25	401.25	411.25	211.25
6	524.50	524.50	514.50	524.50	224.50
7	634.50	633.50	624.50	634.50	234.50

IV. CONCLUSIONS

In this paper an integrated Green production Green supply chain inventory model with linear Green production and Green demand rate has been developed for deteriorating item applying economic load dispatch using genetic algorithm is a significant component of Green supply chain management. In this model the deterioration, the multiple deliveries the partial backordering and the time discounting are considered from the perspective of 3-stage 3-Member Green supply chain, Green Manufacture, Green distributors as well as Green Vendor and economic load dispatch using genetic algorithm. This work can further be extended for 3-stage 3-Member supply chain, multi- Green Manufacture, multi- Green distributors, Green Vendor, economic load dispatch using genetic algorithm and including distributors in the supply chain inventory system. The proposed method was implemented and its performance was evaluated using MATLAB.

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