# Inventory Optimization in Efficient Supply Chain Management

S.R. Singh[1], Tarun Kumar[2]

[1]*Department of Mathematics Sciences, D.N. College, Meerut (U.P) India*
[2]*Department of Computer Science, Banasthali University, Banasthali (Rajasthan), India*

tarunsiet@yahoo.co.in

**Abstract− 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 optimise 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 .**

**Keywords: genetic algorithm, optimisation, Inventory management, supply chain**

## I. INTRODUCTION

Competitiveness in today's marketplace depends heavily on the ability of a company to handle the challenges of reducing lead-times and costs, increasing customer service levels, and improving product quality. Traditionally, sourcing (procurement), production, distribution and marketing have been working independently. Unfortunately, although they may seem to be working towards a common goal, these organizational units have different objectives. Marketing wants to have a high customer service level as well as high sales volume, but they conflict with the objective of production and distribution. Sourcing decisions normally depend solely on minimizing the cost of goods, and production and distribution decisions often consider only maximizing throughput while minimizing production (unit) costs without any consideration for high inventory levels or long lead-times. Supply chain management is the effective coordination and integration of different organizations with different objectives towards a common goal. The great potential for improvement in these objectives through effective supply chain management mechanisms has recently been realized [2].

The inventory management problem is one of maintaining an adequate supply of some item to meet an expected pattern of demand, while striking a reasonable balance between the cost of holding the items in inventory and the penalty (loss of sales and goodwill, say) of running out. The item may be a commodity sold by a store; it may be spare machine parts in a factory; it may be railway wagons; it may be cash in the bank to meet the customers' demand. It is indeed surprising to find that a very wide variety of seemingly different problems can be mathematically formulated as an inventory-control problem. There are, of course, several different models of inventory systems. There are three types of expenses associated with inventory systems. The relative importance of these will depend on the specific system. They are: (i) administrative cost of placing an order, called reorder cost or set cost; (ii) cost of maintaining an inventory, called inventory holding cost a carrying cost, which includes storage charge, interest, insurance, etc., a (iii) shortage cost is a loss of profit, goodwill, etc., when run out of stock. All the above should be optimized for efficient supply chain management [5].

Genetic Algorithm was developed by Holland and his colleagues in the 1960s and 1970s. Genetic Algorithms are inspired by the evolutionist theory explaining the origin of species. In nature, weak and unfit species within their environment are faced with extinction by natural selection. The strong ones have greater opportunity to pass their genes to future generations via reproduction. In the long run, species carrying the correct combination in their genes become dominant in their population. Sometimes, during the slow process of evolution, random changes may occur in genes. If these changes provide additional advantages in the challenge for survival, new species evolve from the old ones. Unsuccessful changes are eliminated by natural selection.

In GA terminology, a solution vector x€X is called an individual or a chromosome. Chromosomes are made of discrete units called genes. Each gene controls one or more features of the chromosome. In the original implementation of GA by Holland, genes are assumed to be binary digits. In later implementations, more varied gene types have been introduced. Normally, a chromosome corresponds to a unique solution x in the solution space. This requires a mapping mechanism between the solution space and the chromosomes. This mapping is called an encoding. In fact, GA works on the encoding of a problem, not on the problem itself.

GA operates with a collection of chromosomes, called a population. The population is normally randomly initialized. As the search evolves, the population includes fitter and fitter solutions, and eventually it converges, meaning that it is dominated by a single solution. Holland also presented a proof of convergence (the schema theorem) to the global optimum where chromosomes are binary vectors.

GA uses two operators to generate new solutions from existing ones: crossover and mutation. The crossover operator is the most important operator of GA. In crossover, generally two chromosomes, called parents, are combined together to form new chromosomes, called offspring. The parents are selected among existing chromosomes in the population with preference towards fitness so that offspring is expected to inherit good genes which make the parents fitter. By iteratively applying the crossover operator, genes of good chromosomes are expected to appear more frequently in the population, eventually leading to convergence to an overall good solution.

The mutation operator introduces random changes into characteristics of chromosomes. Mutation is generally applied at the gene level. In typical GA implementations, the mutation rate (probability of changing the properties of a gene) is very small and depends on the length of the chromosome. Therefore, the new chromosome produced by mutation will not be very different from the original one. Mutation plays a critical role in GA. As discussed earlier, crossover leads the population to converge by making the chromosomes in the population alike. Mutation reintroduces genetic diversity back into the population and assists the search escape from local optima. Reproduction involves selection of chromosomes for the next generation. In the most general case, the fitness of an individual determines the probability of its survival for the next generation [17].

## II. LITERATURE REVIEW

Supply chain network is a complex network, which consists of multiple manufacturers, multiple suppliers, multiple retailers and multiple customers. Markus et al.[19] have developed a supply network model that takes as input the bill of materials, the (nominal) lead times, the demand and cost data, and the required customer service levels. In return, the model generates the base-stock level at each store-the stocking location for a part or an end-product, so as to minimize the overall inventory capital throughout the network and to guarantee the customer service requirements.

A technique to utilize in supply-chain management that supports the decision-making process for purchases of direct goods has been projected by Buffett et al.[9]. RFQs have been constructed on basis of the projections for future prices and demand and the quotes that optimize the level of inventory each day besides minimizing the cost have been accepted. The problem was represented as a Markov Decision Process (MDP) that allows for the calculation of the utility of actions to be based on the utilities of substantial future states. The optimal quote requests and accepts at each state in the MDP were determined with the aid of Dynamic programming. A supply chain management agent comprising of predictive, optimizing and adaptive components called the TacTex-06 has been put forth by Pardoe et al. [10]. TacTex-06 functions by making predictions regarding the future of the economy, such as the prices that will be proffered by component suppliers and the degree of customer demand and then strategizing its future actions so as to ensure maximum profit.

Beamon et al.[11] have presented a study on evaluations of the performance measures that are employed in supply chain models and have also displayed a framework for the beneficial selection of performance measurement systems for manufacturing supply chains Three kinds of performance measures have been recognized as mandatory constituents in any supply chain performance measurement system. New flexibility measures have also been created for the supply chains. The accomplishment of beam-ACO in supply-chain management has been proposed by Caldeira et al.[12]. Beam- ACO has been used to optimize the supplying and logistic agents of a supply chain. A standard ACO algorithm has aided in the optimization of the distributed system. The application of Beam-ACO has enhanced the local and global results of the supply chain. A beneficial industry case applying Genetic Algorithms (GA) has been proposed by Wang et al.[13]. The case has made use of GAs for the optimization of the total cost of a multiple sourcing supply chain system. The system has been exemplified by a multiple sourcing model with stochastic demand. A mathematical model has been implemented to portray the stochastic inventory with the many to many demand and transportation parameters as well as price uncertainty factors. A genetic algorithm which has been approved by Lo [14] deals with the production-inventory problem with backlog in the real situations, with time-varied demand and imperfect production due to the defects in production disruption with exponential distribution. Besides optimizing the number of production cycles to generate a (R, Q) inventory policy, an aggregative production plan can also be produced to minimize the total inventory cost on the basis of reproduction interval searching in a given time horizon. Barlas et al.[15] have developed a System Dynamics simulation model of a typical retail supply chain. The intent of their simulation exercise was to build up inventory policies that enhance the retailer's revenue and reduce costs at the same instant. Besides, the research was also intended towards studying the implications of different diversification strategies. A supply chain model functioning under periodic review base stock inventory system to assist the manufacturing managers at HP to administer material in their supply chains has been introduced by Lee et al.[16].

P. Radhakrishnan et. al.[18] 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.

Many well-known algorithmic advances in optimization have been made, but it turns out that most have not had the expected impact on the decisions for designing and optimizing supply chain related problems. Some optimization techniques are of little use because they are not well suited to solve complex real logistics problems in the short time needed to make decisions and also some techniques are highly problem dependent which need high expertise. This adds difficulties in the implementations of the decision support systems which contradicts the tendency to fast implementation in a rapidly changing world. IO techniques need to determine a globally optimal placement of inventory, considering its cost at each stage in the supply chain and all the service level targets and replenishment lead times that constraint each inventory location.

## III. Genetic Algorithms Based Inventory Optimization Analysis

For the inventory Control to be more effective, the main primary objective is to predict where, why and how much of the control is required and such a prediction is to be made here through the methodology .In the proposed Methodology an appropriate stock levels to be maintained in the approaching periods that will minimize the supply chain inventory cost can be arrived. Supply Chain model is divided into three stages in which the optimization is going to be performed

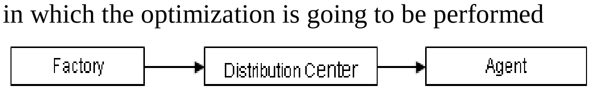


Fig. 1. Three stage supply chain (Studied model)

In this Fig 1., the factory manufactures different products and determines how it would be supplied to the distribution center and how the stocks will be moved to the agents .

The Proposed methodology is aimed at determining the specific product that needs to be concentrated on and the amount of stock levels of the products to be maintained by different members of the supply chain also the methodology analyses whether the stock level .

In our proposed methodology, we are using genetic algorithm for finding the optimal value. The flow of operation of our methodology is clearly illustrated in figure 2 which depicts the steps applied for the optimization analysis

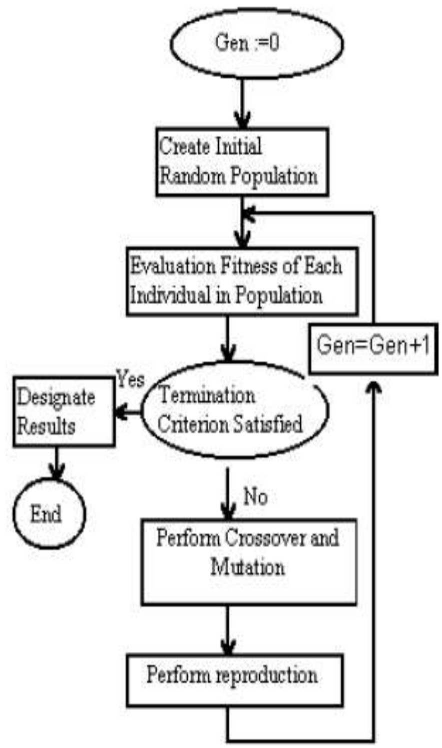


Fig. 2. Genetic Algorithm Structure

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.

*Generation of individuals*: Each individual which is constituted by genes is generated with random values. Here, the chromosome of 3 genes where the random values occupy each gene is generated along with the product representation. A random individual generated for the genetic operation is shown in the Fig. 3. After the generation of the individuals, the number of occurrences of the individual in the past records is determined. This is performed by the function count () and the total number of occurrences of that individual for the particular product is determined. This is equivalent to the number of occurrences of such situation of stock levels for the respective product in all the members throughout the period under consideration.

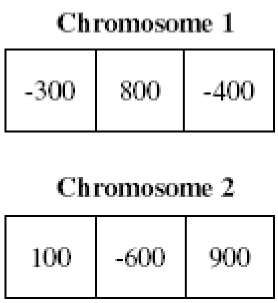


Fig. 3. Chromosome Representation

Evaluation of fitness function: A specific kind of objective function that enumerates the optimality of a solution in a genetic algorithm in order to rank certain chromosome against all the other chromosomes is known as Fitness function. Optimal chromosomes, or at least chromosomes which are near optimal, are permitted to breed and merge their datasets through one of the several techniques available in order to produce a new generation that will be better than the ones considered thus far.
The fitness function is given by:

$$f(i) = \log\left(1 - \frac{n_{occ}(i)}{n_{tot}}\right), \ i = 1,2,3,\cdots,n$$

Where:
nocc (i) = The number of occurrences of the chromosome i in the record set
ntot = The total number of records that have been collected from the past or total number of data present in the record set.

The fitness function mentioned ranks the randomly generated chromosome. Then, the chromosomes are subjected to the genetic operations.

*Genetic Operations:* Once fitness calculation is done, Genetic operations are performed. Selection, Crossover and mutation comprise Genetic operations.

*Selection:* The selection operation is the initial genetic operation which is responsible for the selection of the fittest chromosome for further genetic operations. This is done by offering ranks based on the calculated fitness to each of the prevailing chromosome. On the basis of this ranking, best chromosomes are selected for further proceedings.

*Crossover:* As far as the crossover operation is concerned, a single point crossover operator is used in this study. The first two chromosomes in the mating pool are selected for crossover operation. The crossover operation that is performed for an exemplary case is shown in the following figure.

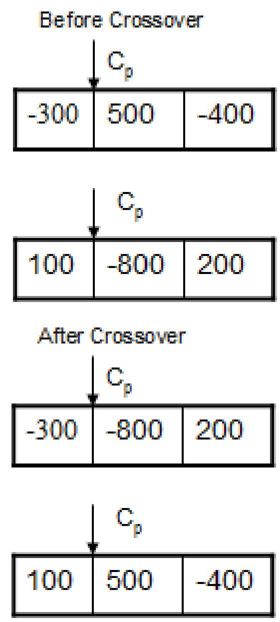


Fig.4. Crossover Operation

The genes that are right of the cross over point in the two chromosomes are swapped and hence the cross over operation is done. After the crossover operation two new chromosomes are obtained.

*Mutation:* The newly obtained chromosomes from the crossover operation are then pushed for mutation. By performing the mutation, a new chromosome will be generated. This is done by a random generation of two points and then performing swaps between both the genes. The illustration of mutation operation is shown in Fig. 5.

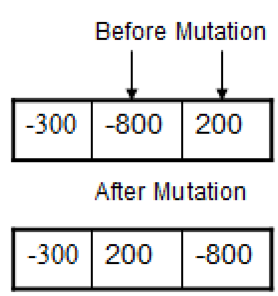


Fig. 5. Mutation

The mutation operation provides new chromosomes that do not resemble the initially generated chromosomes. After obtaining the new chromosome, another random chromosome will be generated. The process explained so far will be repeated along with the new chromosome obtained from the previous process. In other words, at the end of each of the iteration, a best chromosome will be obtained. This will be included with the newly generated random chromosome for the next iteration. Eventually, an individual which is the optimal one among all the possible individuals is obtained. This best chromosome obtained has the optimal information about stock levels of a particular product at each member of the supply chain. From the information it can be concluded that the particular product and its corresponding stock levels play a significant role in the increase of supply chain cost. By controlling the stock level of that particular product at the respective member of the supply chain in the upcoming periods, the supply chain cost can be minimized.

## IV. RESULTS AND DISCUSSIONS

The optimization of inventory control in supply chain management based on genetic algorithm is analyzed with the help of MATLAB. The stock levels for the three different members of the supply chain, factory, distribution center and Agent 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 17 sets of data are given in the table 1 and these are assumed as the records of the past period.

| Factory | Distribution Center | Agent |
|---|---|---|
| 146 | 118 | 532 |
| -491 | -239 | 169 |
| 372 | 573 | -345 |
| -491 | -239 | 169 |
| 888 | -844 | 208 |
| -491 | -239 | 169 |
| -491 | -239 | 169 |
| 792 | -456 | 837 |
| -746 | 721 | -677 |
| 172 | 969 | -407 |
| -491 | -239 | 169 |
| 611 | -295 | -445 |
| -491 | -239 | 169 |
| 482 | -471 | 761 |
| -992 | 268 | -370 |
| -152 | 275 | -345 |
| -491 | -239 | 169 |

Table1. A sample of data sets having stock levels of the members of supply chain

The two initial chromosomes are generated at the beginning of the genetic algorithm as above. These initial chromosomes are subjected for the genetic operators, Crossover and Mutation. The resultant chromosome thus obtained after the application of crossover and mutation As for our iteration value of '100', the resultant chromosome moved towards the best chromosome after the each iterative execution. Hence at the end of the execution of 100th iteration, best chromosome '-491 -329 169' is obtained. While comparing the obtained result from the genetic algorithm with the past records, it can be decided that controlling this resultant chromosome is sufficient to reduce the loss either due to the holding of excess stocks or due to the shortage of stocks. Hence it is proved that the analysis obtains a stock level that is a better prediction for the inventory optimization in supply chain management.

## V. CONCLUSION

Inventory management is a significant component of supply chain management. We have discussed a method based on genetic algorithm to optimise inventory in supply chain management we also focus on how to specifically 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 .we apply our methods on three stage supply chain studied model for optimization. The proposed method was implemented and its performance was evaluated using MATLAB.

## REFERENCES

[1] Sarmiento, A. Rabelo, L. Lakkoju, R. Moraga, R.,"Stability analysis of the supply chain by using neural networks and genetic algorithms", Proceedings of the winter Simulation Conference, pp: 1968-1976, 2007.

[2] Joines, J.A. Gupta, D. Gokce, M.A. King, R.E. Kay, M.G., "Supply Chain Multi-Objective Simulation Optimization", Proceedings of the winter Simulation Conference, vol.2, pp: 1306- 1314, 2002

[3] "Optimization Engine for Inventory Control", white paper from Golden Embryo Technologies pvt. Ltd., Maharastra, India, 2004.

[4] Levi, R., Martin Pal, R. O. Roundy, D. B. Shmoys. "Approximation algorithms for stochastic inventory control models", Mathematics of Operations Research 32 , pp: 284-302, 2007.

[5] Mrs. S. Narmadha , Dr. V. Selladurai, "Multi-factory, Multi-Product Inventory Optimization using Genetic Algorithm for Efficient Supply Chain Management" ,International Journal of Computer Science and Network Security, VOL.9 No.12, December 2009

[6] D. Pardoe and P. Stone, "An autonomous agent for supply chain management". In G. Adomavicius and A. Gupta, editors, Handbooks in Information Systems Series: Business Computing. Elsevier, 2007 Conference,March6-7, 2009.

[7] Ettl,M., Feigin, G.E. ,Lin, G.Y. and Yao, D.D. "A Supply Network Model with Base stock control and Service Requirements" ,Operations Research ,48(2) , 216-232 2000. Graves S.C. and Willems S.P. "Optimizing Strategic Safety Stock

[8] Placement in Supply Chains" , Manufacturing & Service perations Management Vol. 2, No. 1, Winter 2000, pp. 68–83

[9] S. Buffett and N. Scott, "An Algorithm for Procurement in Supply Chain Management", AAMAS-04 Workshop on Trading Agent Design and Analysis, New York 2004 .

[10] D. Pardoe and P. Stone, "An Autonomous Agent for Supply Chain Management". In: Handbooks in Information Systems Series: Business Computing, Adomavicius, G. and A. Gupta (Eds.). Elsevier. Amsterdam 2007.

[11] B.M. Beamon, "Supply chain design and analysis: Models and methods", International Journal on Production Economics, 55: 281-294 1998.

[12] J.L. Caldeira, R.C. Azevedo, C.A. Silva and J.M.C. Sousa, "Supply-chain management using ACO and beam-ACO algorithms", Proceedings of the IEEE International Fuzzy Systems Conference, July 23-26, London, pp. 1-6 2007.

[13] K. Wang and Y. Wang, "Applying Genetic Algorithms to Optimize the Cost of Multiple Sourcing Supply Chain Systems – An Industry Case Study", Studies on Computational Intelligence, Vol. 92, pp. 355-372 2008.

[14] Chih-Yao Lo, "Advance of Dynamic Production-Inventory Strategy for Multiple Policies using Genetic Algorithm", Information Technology Journal, Vol. 7, pp. 647-653 2008.

[15] Y. Barlas and A. Aksogan, 1996, "Product Diversification and Quick Response Order Strategies in Supply Chain Management", 14th International Conference of the System Dynamics Society 1996 Cambridge, Massachusetts, USA, pp. 51-56.

[16] H.L. Lee and C. Billington, 1995. The evolution of supply-chain management models and practice at Hewlett-Packard. Interface, 25: 42-63.

[17] Abdullah Konak, David W. Coit, Alice E. Smith, "Multi-objective optimization using genetic algorithms" Reliability Engineering and System Safety 91 (2006) 992–1007 Elsevier Ltd

[18] P.Radhakrishnan, V.M.Prasad and M. R. Gopalan, "Genetic Algorithm Based Inventory Optimization Analysis in Supply Chain Management" IEEE International Advance Computing Conference, Patiala Pg-418 422 March6-7, 2009

[19] Markus Ettl, Gerald E. Feigin, Grace Y. Lin, David D. Yao, "A Supply Network Model with Base-Stock Control and Service

[20] Requirements" OPERATIONS RESEARCH Vol. 48, No. 2, March-April 2000, pp. 216-232DOI: 10.1287/opre.48.2.216.12376