Inventory Optimization in Supply Chain Management using Genetic Algorithm

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Summary
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.

Keywords:
Supply Chain Management, Inventory control, Inventory Optimization, Genetic Algorithm, supply chain cost.

1. Introduction

Notable changes in the market scenario often occur as a result of Global competition, shorter product life cycles, dynamic changes of demand patterns and product varieties and environmental standards thus enforcing the manufacturing enterprises to deliver their best in order to strive [1]. The competitiveness of a company in the modern-day market place is determined by more than one vital feature such as the decrease in lead times and expenses, enhancement of customer service levels and upgrading the product quality [11]. The business organizations have started to ponder over the supply chains due to the aforesaid factors. A supply chain can be defined as a collection of companies offering products and services to the market. A supply chain can be illustrated as an incorporation of multiple entities that work in coalition towards 1) obtaining raw materials, (2) converting these raw materials into precise end products, and (3) delivering the end products to retailers [19]. Acquirement of raw materials and manufacturing items at one or more factories, shipping the items to diverse warehouses for storage and in turn shipping them to the corresponding retailers or customers are all part of the conventional supply chain [20]. Therefore, a valuable coordination and merger of organizations with distinct objectives to attain a common goal can be called as a supply chain.

Supply chain management involves a set of procedures that aid in the proficient integration of suppliers, manufacturers, warehouses and stores to ensure appropriate production and distribution of right quantities to the right location in right time and reducing the total supply chain cost as a result in addition to fulfilling service level requirements. The manufacturer, who acquires the raw materials, converts them into end products and distributes the same to the customers, is regarded as the manager of the supply chain. The management of the dynamic demand is a huge confront that numerous supply chain firms indented towards decreasing the supply chain costs besides enhancing customer service levels face [10]. The concepts of supply chain management incorporates a wide range of activities that support the planning, implementation and control manufacturing and the delivery processes right from the source of raw material to the spot where the end product is utilized [6]. Acute issues in supply chain management arise out of shorter product lifecycles that lead to higher demand uncertainty and the action on global markets consequently increasing the supply chain complexity [11, 8]. From the operational point of view, this research addresses four problem areas including Inventory management and control; production, planning and scheduling; information sharing, coordination, monitoring; and operation tools [9].

A steady ascent in the levels of customer service has made the efficient and effective management of inventory in the supply chain inevitable [5]. The overload or shortage of inventories has a notable influence on the total supply chain cost. As a result, inventory optimization has emerged one of the newest topics when the supply chain management is taken into consideration [3], [15], [17].

A collection of items held by an organization for future utilization is known as inventory and a set of policies known as the inventory system examine and control the same [4]. The inventory can be stocked by diverse stages along the production and distribution supply chain [3]. The inventory system aids in estimating the amount of each item to be hoarded, when the low items should be replenished, and the number of items that need to be ordered or manufactured once replenishment becomes necessary [4]. An supply manager is responsible to arrive at a decision on which offers to accept besides updating the estimated future inventory replacement costs.

Inventory optimization application aids in the enhancement of inventory control and its management across an extended supply network, which organizes the latest techniques and technologies. Optimization of inventory strategies to enhance customer service, reduce lead times and costs and meet market demand [3], [15], [17] are some of the design goals of Inventory optimization. Inventory control describes the design and management of the storage policies and procedures for raw materials, work-in-process inventories, and usually, final products [19]. Effective handling of the supply chain can result in reduced costs and lead times besides remarkable enhancement in responsiveness to changing customer demands and subsequently optimal inventory [8]. Estimation of the precise amount of inventory at each point in the supply chain devoid of excesses and shortages despite minimizing the total supply chain cost is a chief concern for the inventory and supply chain managers. 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 [20].

Genetic algorithm is a randomized search methodology having its roots in the natural selection process. Initially the neighborhood search operators (crossover and mutation) are applied to the preliminary set of solutions to acquire generation of new solutions. Solutions are chosen randomly from the existing set of solutions where the selection probability and the solution's objective function value are proportional to each other and eventually the aforesaid operators are applied on the chosen solutions. Genetic algorithms have aided in the successful implementation of solutions for a wide variety of combinatorial problems.

This paper is the enriched version of the previously published paper which analyses and exhibits the experimental results [27]. In this paper, we have developed a novel and efficient approach using Genetic Algorithm 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. The practical problem that is arising usually in inventory management is the dynamic nature of the excess stock level and shortage level over all the periods. The necessary operation to do is to determine the stock level that occurs in a maximum rate. So, the optimization will be effective only if the maximum occurrences of stock level are considered. The fitness function of the genetic algorithm we have used is formulated in such a way that it will determine the necessary stock level from the past periods.

The remainder of the paper is organized as follows; Section 2 gives a brief review of relevant researches on inventory optimization. The brief review of the proposed concept is presented in Section 3 and conclusions are summed up in Section 4.

2. Related Works

A fresh genetic algorithm (GA) approach for the integrated inventory distribution problem (IIDP) has been projected by Abdel et al. [26]. They have developed a genetic representation and have utilized a randomized version of a formerly developed construction heuristic in order to produce the initial random population.

In [8] Pupong et al., have put forth an optimization tool that works on basis of a multi-matrix real-coded Generic Algorithm (MRGA) and aids in reduction of total costs associated within supply chain logistics. They have incorporated procedures that ensure feasible solutions such as the chromosome initialization procedure, crossover and mutation operations. They have evaluated the algorithm with the aid of three sizes of benchmarking dataset of logistic chain network that are conventionally faced by most global manufacturing companies.

A technique to utilize in supply-chain management that supports the decision-making process for purchases of direct goods has been projected by Scott et al. [20]. 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 David et al. [6]. 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. [19] have presented a study and evaluations of the performance measures 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 been also created for the supply chains.

The accomplishment of Beam-ACO in supply-chain management has been proposed by Caldeira et al. [21]. 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 Kesheng et al. [22]. 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 souring 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 Chih-Yao Lo [23] to deal 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 basis of the reproduction interval searching in a given time horizon.

In [24] Barlas et al., 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. [25]. The inventory levels across supply chain members were obtained with the aid of a search routine.

3. Inventory Optimization Analysis Using GA

The proposed method uses the Genetic Algorithm 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 K-means clustering as assistance. In practice, the supply chain is of length n, means having n number of members in supply chain such as factory, distribution centers, suppliers, retailers and so on. Here, for instance we are going to use a three stage supply chain that is illustrated in the figure 1. Our exemplary supply chain consists of a factory, distribution center1 and distribution center 2.

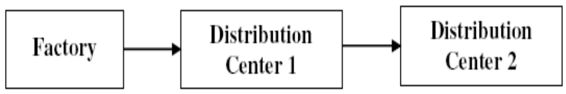

Fig 1. Three member supply chain

In the supply chain we are illustrated, the factory is the massive stock holding area where the stocks are manufactured as per the requirement of the distribution center 1. Then the distribution center 1 will take care of the stock to be supplied for the distribution center 2. 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 three members of the supply chain, factory, distribution center1 and distribution center 2.

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.

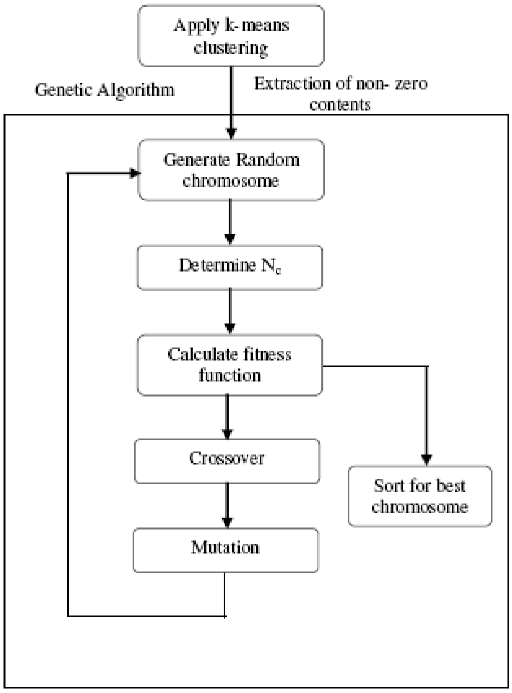

Fig 2. Operational flow of proposed methodology

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 K-means Clustering algorithm.

After the process of K- means clustering is performed, the work starts its proceedings on Genetic algorithm, the heart of our work. For the 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.

3.1. Chromosome Representation

The randomly generated initial chromosome is created by having the stock levels within the lower limit and the upper limit for all the contributors of the supply chain, factory and the distribution centers. As known, chromosome is constituted by genes which defines the length of the chromosomes. The stock level of each member of the chromosome is referred as gene of the chromosome. Hence for n length supply chain, the chromosome length is also n. As we are using only three members of the chain, the length of the chromosome n is 3, i.e. 3 genes. And the chromosome representation is pictured in figure 3. Each gene of the chromosome is representing the amount of stock that is in excess or in shortage.

Chromosome 1

-300	800	-400

Chromosome 2

100	-600	900

Fig. 3. Chromosome representation

These kinds of chromosomes are generated for the genetic operation. Initially, only two chromosomes will be generated and from the next generation a single random chromosome value will be generated. The chromosomes thus generated is then applied to find its number of occurrences in the database content by using a $Select\ count()$ function

The function will give the number of occurrences of the particular amount of stock level for the three members N_c that are going to be used further in the fitness function.

3.2. Fitness Function

Fitness functions ensure that the evolution is toward optimization by calculating the fitness value for each individual in the population. The fitness value evaluates the performance of each individual in the population.

$$f(k) = \log\left(1 - \frac{N_c}{N_p}\right), \quad k = 1,2,3\cdots\cdots, m$$

Where, N_c is the number of counts that occurs throughout the period.

N_p is the total number of inventory values obtained after clustering.

m is the total number of chromosomes for which the fitness function is calculated.

The fitness function is carried out for each chromosome and the chromosomes are sorted on the basis of the result of the fitness function. Then the chromosomes are subjected for the genetic operation crossover and mutation.

3.3. 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.

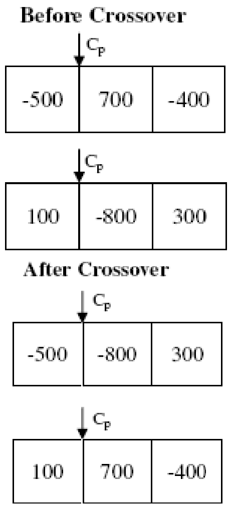

Fig.4. Chromosome representation

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.

3.4. 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 below.

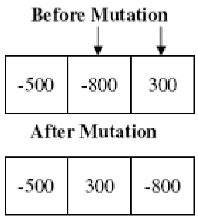

Fig. 5. Mutation

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. Then again the process repeats for a particular number of iteration while the two chromosomes that are going to be subjected for the process is decided by the result of the fitness function. Each number of iteration will give a best chromosome and this is will be considered to find an optimal solution for the inventory control. When the number of iterations is increased then the obtained solution moves very closer to the accurate solution. More the number of iterations results in more accurate optimal solution. Eventually with the help of the Genetic algorithm, the best stock level to be maintained in the members of the supply chain could be predicted from the past records and so that the loss due to the holding of excess stock level and shortage level can be reduced in the upcoming days.

4. Experimental Results

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 1, distribution center 1 and distribution center 2 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 28 sets of data are given in the table 1 and these are assumed as the records of the past period.

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

Sl.No	Factory	Distribution center1	Distribution center2
1	-591	-329	269
2	-479	-796	-548
3	-591	-329	269
4	494	392	285
5	-591	-329	269
6	372	573	-345
7	999	-934	108
8	146	118	532
9	-591	-329	269
10	-591	-329	269
11	-746	721	-677
12	792	-456	837
13	-591	-329	269
14	-550	-634	158
15	611	-295	-443
16	497	-170	847
17	-992	268	-270
18	162	969	-507
19	482	-471	761
20	-591	-329	269
21	671	-768	-367
22	446	-916	129
23	-278	582	-573
24	-758	-766	367
25	-208	-306	403
26	-437	-850	407
27	-591	-329	269
28	297	342	686

The two initial chromosomes are generated at the beginning of the genetic algorithm are '-546 -802 209' and '-155 248 -759'. These initial chromosomes are subjected for the genetic operators, Crossover and Mutation. The resultant chromosome thus obtained after the application of crossover and mutation is '546 -759 248'. 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 100^{th} iteration, best chromosome '-591 -329 269' 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.

5. Conclusion

Inventory management is a significant component of supply chain management. Supply chain costs need to be minimized by handling inventory levels in numerous production and distribution operations related with diverse chain stages and the members of a supply chain are responsible for the same. We have proposed a innovative and efficient methodology that works with the aid of Genetic Algorithms in order to facilitate the precise determination of the most probable excess stock level and shortage level required for inventory optimization in the supply chain such that minimal total supply chain cost is ensured. MATLAB 7.4 was utilized to implement the proposed approach and to evaluate the performance. The genetic algorithm performed well as anticipated. Thus the proposed work proffers a better prediction of stock levels amid diverse stock levels at various members of the supply chain. Henceforth the stock level obtained is the optimal value that is necessary in order to determine the stock levels needed to be hoarded at the holding points in order to ensure minimal supply chain cost.

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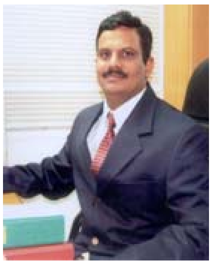

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