Multi-factory, Multi-Product Inventory Optimization using Genetic Algorithm for Efficient Supply Chain Management

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Summary
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. 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. 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. Genetic Algorithms is used to achieve inventory optimization in the supply chain. The complexity of the problem increases when more distribution centers and agents were involved. The consideration of multiple products and multiple factories leading to very complex inventory management process has been resolved in this work.

Key words:
Supply Chain Management, Inventory Control, Inventory Optimization, Genetic Algorithm, Supply Chain Cost

1. Introduction

Supply Chain Management (SCM) is an efficient management of the complete end to end process, starting from the design of the product or service to the time when it has been sold, consumed and finally gotten rid of by the consumer. This complete process includes product design, procurement, planning and forecasting, production, distribution, fulfillment and after sales supports. A company's competitiveness in the global economy can be increased only with the aid of effective SCM. This involves complex strategic, tactical, and operational decisions that often require an in-depth understanding of industry-specific issues, which ranges from network design to production sourcing and from production planning and inventory management to scheduling [1].

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.

1.1 Inventory Control in Supply Chain Management

It has been stated by several people that the focus point of supply chain management is inventories and inventory control. To transfer their focus from scheming logistical costs to investigate supply chains [2] few food manufacturers and grocers formed Efficient Consumer Response in the year 1992. The major competitive factor for companies focused on value creation for end consumers is the customer service. In general, firms hold inventory for two major reasons, to lessen costs and to improve customer service. The inspiration for each varies as firms stabilize the problem of having too much inventory (which can direct to high costs) versus having very small inventory (which can direct to lost sales) [3].

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Supply chain management leads to cost savings, mainly in the course of lessening in inventory. Inventory costs have got reduced by about 60% from 1982, whereas transportation costs have fallen by 20% [4]. These cost savings have led many people to follow inventory-reduction strategies in the supply chain. To deal with inventory, firms make use of one of three common approaches. First of all, the majority of retailers make use of an inventory control approach, monitoring inventory levels by item. The second thing is, manufacturers are typically more concerned with production scheduling and use flow management to deal with inventories. Third, numerous firms (for the majority part those handling raw materials or in extractive industries) do not keenly deal with inventory [5].

The inventory management is influenced by the nature of demand, depending on whether demand is derived or independent. Independent demand comes up from demand for an end product. End products are found all through the supply chain. By definition, a self-governing demand is uncertain, meaning that extra units or safety stock must be accepted to guard against stock outs. While managing uncertainty, the objective should be to minimize the inventory levels and also meet customer expectation. Supply chain coordination can reduce the ambiguity of intermediate product demand, in that way reducing inventory costs [3, 6].

Since Ford Harris' renowned Economic Order Quantity (EOQ) model was first proposed in 1913, the inventory control has been rewarded immense awareness for a long time because of its significance in the cost control. To lessen the total expected inventory costs per unit time while satisfying the customer demand on time [7] is one of the major objectives. Inventory control for large-scale supply chains is well recognized [8-10] as an essential problem with several applications together with manufacturing systems, logistics systems, communication networks, and transportation systems [11]. It is essential to locate the apt mechanism for coordinating the inventory processes that are controlled by independent partners, in order to find out the right ordering quantity and inventory level amid partners in the chain. For example, the manufacturer make use of the periodic review and lot sizing policy to manage its inventory and the retailer employs the periodic review with target stock level to control its inventory and more [12].

1.2 Inventory Optimization in Supply Chain Management

The effective management of the supply chain has become unavoidable these days due to high expectation in customer service levels [13]. The supply chain cost was immensely influenced by the overload or shortage of inventories. Thus inventory optimization has transpired into one of the most important topics as far as supply chain management is considered [14-16].

To exploit economies of scale and order in large lots, the important issues in supply chain is to optimize the inventory level by considering various costs in maintaining a high service level towards the customer. Since, the cost of capital tied up in inventory is more, the inventory decision in the supply chain should be coordinated without disturbing the service level. The coordination of inventory decision within an entity is viable, but not between the entities. So the integration of the entities to centralize the inventory control is needed.

Inventory Optimization [IO] application organizes the latest techniques and technologies, thereby assisting the improved inventory visibility, the enhancement of inventory control and its management across an extended supply network. Some of the design objectives of inventory optimization are to optimize inventory strategies, thereby enhancing customer service, reducing lead times and costs and meeting market demand [14-16]. The design and management of the storage policies and procedures for raw materials, work-in-process inventories, and typically, final products are illustrated by the inventory control. The costs and lead times can be reduced and the responsiveness to the changing customer demands can be significantly improved and subsequently inventory can be optimized by the effective handling of the supply chain [17].

There are several reasons for manufacturers' increasing focus on optimizing inventory by applying the latest tools and techniques for inventory control. Traditionally, competitive pressure has always driven manufacturers to seek enhanced capabilities to reduce inventory levels; to enhance service levels and supply availability; and to establish the right product inventory mix and level in each geography and channel. A key driver of the renewed focus on inventory lies in the recognition that traditional techniques are failing to reign in inventories in the wake of increased supply chain complexity. This complexity is characterized by increased uncertainty. Demand is more volatile and therefore less predictable. This is true not only for aggregate demand but for forecasting splits and volumes across channels and markets. Traditionally three strategies have been employed by manufacturers to address uncertainty; a) increase inventory levels to hedge against uncertainty; b) develop supply chain flexibility to be more responsive to uncertainty; c) improve forecast accuracy so that less uncertainty propagates to the manufacturing floor. Inventory optimization techniques and technologies map to the flexibility and accuracy strategies. [18].

Inventory Optimization characterizes the supply network uncertainty present in a variety of specific steps or links in manufacturing and distribution processes. Advanced mathematical models are then solved to identify optimal inventory policies, stocking locations, or quantities. The uncertainty addressed by IO include: demand uncertainty, cycle time variability and replenishment lead time variability.[18] Efficient management of the supply chain, i.e. the reduction of the costs and lead times and vastly enhanced responsiveness to the changing customer demands lead to an optimized inventory.

2. Related Works - Review

2.1 Review of Base-Stock based Inventory Control Models

The inventory control problem for a single class assembly network which operates under a modified echelon base-stock policy was studied by Vecchio and Paschalidis [19]. An approach to find close-to-optimal echelon stock levels that minimize inventory costs while guaranteeing stockout probabilities to stay below some predefined levels was developed by them. They reduced the safety stock selection to a deterministic nonlinear optimization problem on the basis of the large deviations techniques. In addition, they analyzed as to how a supplier can interact with a buyer to reach a mutually beneficial mode of operations, using their inventory control approach. Their interaction takes the form of a supply contract by which explicit QoS guarantees is enforced. The applications in a distributed fashion with neither the supplier nor the buyer revealing their corresponding cost structures applying the joint optimization algorithm was proposed by the authors.

A model of supply chain consisting of n production facilities in tandem and producing a single product class was considered by Ioannis CH. Paschalidis et al. [20]. The finished goods inventory maintained in front of the most downstream facility is used to meet the external demand while backlogging of unsatisfied demand was performed. The facility at stage 1 produced if inventory has fallen below a certain level w_i and idles otherwise on the basis of a base-stock production policy adopted at each stage of the supply chain. In order to minimize expected inventory costs at all stages subject to maintaining the stock out probability at stage1 below a prescribed level, they necessitated the optimization of the hedging vector W= $(w_1,...,w_n)$. They made assumptions on demand and production processes that included auto correlated stochastic processes, which were relatively general modeling. They have combined analytical (Large derivations) and sample path based (perturbation analysis) techniques to solve the stochastic optimization problem. The existence of a natural synergy between those two approaches has been demonstrated.

An attempt was made to optimize the inventory (i.e. base-stock) levels of a single product at different members in a serial supply chain with the objective of minimizing the Total Supply Chain Cost (TSCC), by Sudhir Ryan Daniel and Chandrasekharan Rajendran [21] and Radhakrishnan et al [22]. The performance measure considered, which is a good representation of the system-wide total cost is the TSCC. In order to optimize the base-stock levels, a genetic algorithm (GA) has been proposed. To analyze the performance of the supply chain (operating with deterministic and stochastic replenishment lead times) for the base-stock levels that are generated by the proposed GA and other solution procedures considered in this study, different supply chain settings are simulated. They demonstrated that their proposed GA required significantly less computing effort to perform very well in terms of yielding solutions that are not significantly different from the optimal solutions (obtained through complete enumeration of solution space).

A beneficial industry case applying Genetic Algorithms (GA) has been proposed by K.Wang and Y.Wang [23]. The case has made use of GAs for the optimization of the total cost of 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 [24] 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. The inventory levels across supply chain members were obtained with the aid of a search routine.

2.2 Review of Optimization based Inventory Control Models

Sukran Kadipasaoglu et al. [1] provided a study on the market characteristics and competitive priorities, manufacturing environment, logistics and distribution activities, and supply chain planning and control activities for polymer manufacturers. They have described polymer distribution network optimization, production/distribution planning, production scheduling, demand management, available-to-promise, and inventory planning activities pertaining to supply chain planning and control. Besides, they illustrated the applications existing in a commercial DSS that support these activities. They have as well described about diverse issues that continue to confront supply chain managers in polymer manufacturing. It encompasses forecasting for the huge number of product–customer combinations, identification of safety stock requirements, administering production schedule changes, business process management throughout DSS implementation and data mapping for decision support. Their research contributes to the supply chain literature by proffering a suitable context for investigating supply chain-related issues. Through discussion and characterization of the polymer supply chain, they recognized the specific issues of concern to potential researchers and to supply chain professionals.

The effect of product variety on supply-chain performance, which is measured in terms of expected lead time and expected cost at the retailers, was analyzed by Ulrich W. Thonemann and James R. Bradley [25]. They took a supply chain with a single manufacturer and multiple retailers into account. If setup times are significant, the effect of product variety on cost where the cost increases proportionally to the square root of product variety is substantially greater than that suggested by the risk-pooling literature for perfectly flexible manufacturing processes.

An illustration that underestimating the cost of product variety, leads companies to offer product variety that is greater than optimal was made as well. In conclusion, they illustrated that by reducing the setup time, the unit manufacturing time, the number of retailers, or the demand rate the supply-chain performance can be managed. The fact that complex mathematical approaches are often not applied in practice was recognized by the authors. Nevertheless, practitioners who used the simple models to estimate the effect of their decisions often appreciated these models.

The inventory and supply chain managers are mainly concerned about the estimation of the exact amount of inventory at each point in the supply chain free of excesses and shortages although the total supply chain cost is minimized. Owing to the fact that shortage of inventory yields to lost sales, whereas excess of inventory may result in pointless storage costs, the precise estimation of optimal inventory is indispensable [26]. In other words, there is a cost involved in manufacturing any product in the factory as well as in holding any product in the distribution center and agent shop. More the products manufactured or held, higher will be the holding cost. Along with this, low lead time results in holding of the excess stock levels and hence the increase in the holding cost. Meanwhile, there is possibility for the shortage of products. For the shortage of each product there will be a shortage cost. Holding excess stock levels as well as the occurrence of shortage for products lead to the increase in the supply chain cost. The factory may manufacture any number of products, each supply chain member may consume a few or all the products and each product is manufactured using a number of raw materials sourced from many suppliers. All these factors pose additional challenge in extracting the exact product and the stock levels that influence the supply chain cost heavily.

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. For example, 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. Also some techniques are highly problem-dependent and 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.

3. Objectives

The supply chain cost can be minimized by maintaining optimal stock levels in each supply chain member. There is a necessity of determining the inventory to be held at different stages in a supply chain that will minimize the total supply chain cost i.e., minimizing holding and shortage cost**.** The approach aims to make use of the meta heuristic algorithms like Genetic algorithm for the prediction of the optimal stock levels to be maintained, so as to minimize the total supply chain inventory cost, comprising holding and shortage costs at all members of the supply chain. The genetic algorithm is proposed that considers all these factors that are mentioned hitherto such that the analysis paves the way for minimizing the supply chain cost by maintaining optimal stock levels in each supply chain member.

3.1 Genetic Algorithm (GA)

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.

The robustness of the Genetic algorithms as search techniques have been theoretically and empirically proved [27]. The artificial individual is the basic element of a GA. An artificial individual consists of a chromosome and a fitness value, similar to a natural individual. The individual's likelihood for survival and mating is determined by the fitness function [28]. In accordance with the Darwin's principle, individuals superior to their competitors, are more likely to promote their genes to the next generations. In accordance with this concept, in Genetic Algorithms, a set of encoded parameters are mapped into a potential solution, named chromosome, to the optimization problem [29]. The population of candidate solutions is obtained through the process of selection, recombination, and mutation performed in an iterative manner. [30].

Chromosomes refer to the random population of encoded candidate solutions with which the Genetic algorithms initiate with. [27]. Then the set (called a population) of possible solutions (called chromosomes) are generated [31]. A function assigns a degree of fitness to each chromosome in every generation in order to use the best individual during the evolutionary process [32]. In accordance to the objective, the fitness function evaluates the individuals [30]. Each chromosome is evaluated using a fitness function and a fitness value is assigned. Then, three different operators- selection, crossover and mutation- are applied to update the population. A generation refers to an iteration of these three operators [33]. The promising areas of the search space are focused in the selection step. The selection process typically keeps solutions with high fitness values in the population and rejects individuals of low quality [30]. Hence, this provides a means for the chromosomes with better fitness to form the mating pool (MP) [31].

After the process of Selection, the Crossover is performed. In the crossover operation, two new children are formed by exchanging the genetic information between two parent chromosomes (say C1 and C2 which are selected from the selection process) [31]. A crossover point is chosen at random by the crossover operator. At this point, two parent chromosomes break and then exchange the chromosome parts after that point. Consequently, the partial features of two chromosomes are combined to generate two off springs. The chromosome cloning takes place when a pair of chromosomes does not cross over, thus creating off springs that are exact copies of each parent [32]. The ultimate step in each generation is the mutation of individuals through the alteration of parts of their genes [30]. Mutation alters a minute portion of a chromosome and thus institutes variability into the population of the subsequent generation [31]. Mutation, a rarity in nature, denotes the alteration in the gene and assists us in avoiding loss of genetic diversity [30]. Its chief intent is to ensure that the search algorithm is not bound on a local optimum [32].

4. Inventory Optimization Analysis Using Genetic Algorithm for Multi-Factory, Multi Products-Dealing with Selective Products

The inventory control for more number of factories, multi products along with different levels of supply chain and multiple factories with each factory manufacturing selective products as well as agents under a distribution center dealing with selective products of the supply chain is a more complex task. These considerations may lead to very complex inventory management process involving the possible complexities the supply chain to be dealt with in realty may pose. Thus the complexity of the problem has been increased to a more likely supply chain structure. To make the inventory control effective, the most primary objective is to predict where, why and how much of the control is required which is made here through the GA methodology proposed. To accomplish the same, Genetic algorithm is used and the optimal number of units of a specific product at each member of supply chain that needs to be kept in the level of control is determined on the basis of the knowledge of the past records. This leads to an easy estimation of the stock levels of the respective products to be maintained at different members of the chain in the upcoming periods.

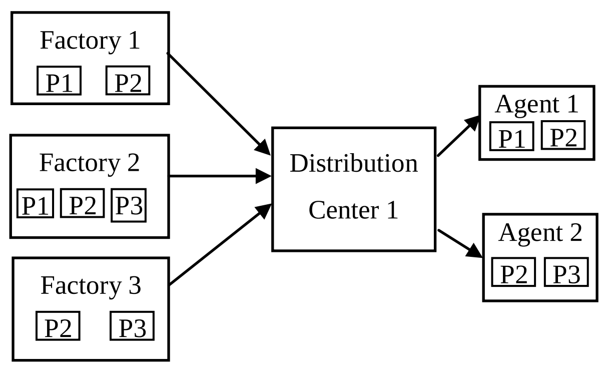

Fig. 1 Three Stage-6 Member Supply Chain

For instance, a three stage supply chain having six members is depicted in Fig. 1. As shown in the supply chain example, there are 3 factories which are the parents of the chain and they are having 1 distribution center Distribution center 1. The Distribution center further comprises two agents, Agent 1 and Agent 2. Also in the example case, factory 1 manufactures products P1 and P2, factory 2 manufactures products P1, P2, P3 and factory 3 manufactures products P2 and P3 that would be supplied to the distribution center. From the distribution center, the stocks will be moved to the corresponding agents. In the example case, Agent 1 deals with products P1 and P2; Agent 2 deals with products P2 and P3 only.

The proposed methodology is aimed at determining the specific product that needs to be concentrated on and the amount of stock levels of the product to be maintained by the different members of the supply chain. Also, the methodology analyses whether the stock level of the particular product needs to be in abundance, in order to avoid shortage of the product or needs to be held minimal in order to minimize the holding cost.

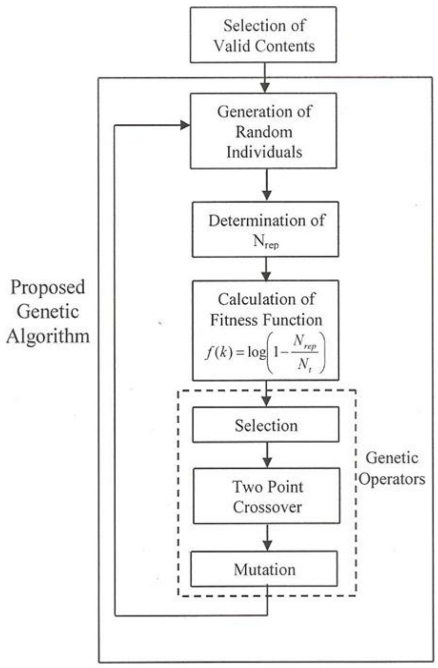

Fig. 2 Genetic Algorithm steps for the proposed inventory management analysis

The methodology as shown in Fig. 2 would analyze the past records very effectively and thus facilitate efficient inventory management with the aid of Genetic Algorithm. The analysis is initiated by the selection of valid records. The validation of records is done over the records of past periods. The stock levels at the different supply chain members are held in the dataset for respective products. For the valid record set selection, records having nil values are neglected and the records having positive or negative values are selected for the analysis. This can be done by means of clustering algorithms, extraction algorithms or by any of the data mining functions. Hence the extraction function results in data sets having either positive or negative values.

Table 1: The dataset format for the analysis taken from the past periods

Distribution													
Factory1 (F1)		Factory2(F2)			Factory3(F3)		Center 1(D1)			Agent 1(A1)		Agent 2(A2)	
P1	P2	P1	P2	P3	P2	P3	P1	P2	P3	P1	P2	P2	P3
100	-20	36	-65	42	25	-170	48	23	-79	100	-200	289	-423

The record set having positive values represents excess stock levels and the negative values represent shortage level of a particular product at a particular member of the supply chain. Then the data set is subjected to Genetic Algorithm and the various steps performed in the genetic algorithm are discussed below.

4.1 Generation of individuals

Each individual which is constituted by genes is generated with random values. Here, the chromosome of 14 genes where the random values occupy each gene is generated along with the member-product representation. A random individual generated for the genetic operation is shown in the Fig. 3.

F1 P1	F1 P2	F2 P1	F2 P2	F2 P3	F3 P2	F3 P3	D1 P1	D1 P2	D1 P3	A1 P1	A1 P2	A2 P2	A2 P3
300	-35	100	67	-87	45	-90	84	-84	90	200	-300	72	-90

Fig. 3 Random individual generated for the genetic operation

After the generation of the individuals, the number of occurrences of the individual in the past records is determined by the function count ( ). This is equivalent to the number of occurrences of such situation of member-product stock levels throughout the records of the past period under consideration.

4.2 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 so far.

The fitness function is given by:

$$f(k)=\log\left(1-\frac{N_{rep}}{N_t}\right),\ k=1,2,3\cdots\cdots,m \qquad (1)$$

where,

N_{rep} is the number of repetitions of records of similar stock levels that occurs throughout the period;

N_t is the total number of records of inventory values obtained after clustering;

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

In the fitness function, the ratio (N_{rep} / N_t) plays the role of finding the probability of occurrence of a particular record of inventory values; and log [1- (N_{rep} / N_t)] will ensure minimum value corresponding to the maximum probability; So, the fitness function is structured to retain the minimum value corresponding to the various

chromosomes being evaluated iteration after iteration and this in turn ensures that the fitness function evolution is towards optimization.
The fitness function is carried out for each chromosome and the chromosomes are sorted on the basis of the result of the fitness function and ranked. The chromosome generating value as minimum as possible will be selected by the fitness function and will be subjected further to the genetic operations, crossover and mutation.

4.3 Genetic operations

Once fitness calculation is done, Genetic operations are performed. Selection, Crossover and Mutation comprise Genetic operations.

4.3.1 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 with minimum fitness function value are selected for further proceedings.

4.3.2 Crossover

Among the numerous crossover operators in practice, for the complex operation, a two point crossover is chosen. From the matting pool, two chromosomes are subjected for the two point crossover. The crossover operation performed in this analysis is pictured in Fig. 4.
As soon as the crossover operation is completed, the genes of the two chromosomes present within the two crossover points get interchanged. The genes before the crossover point C1 and the genes beyond the crossover point C2 remain unaltered even after the crossover operation.

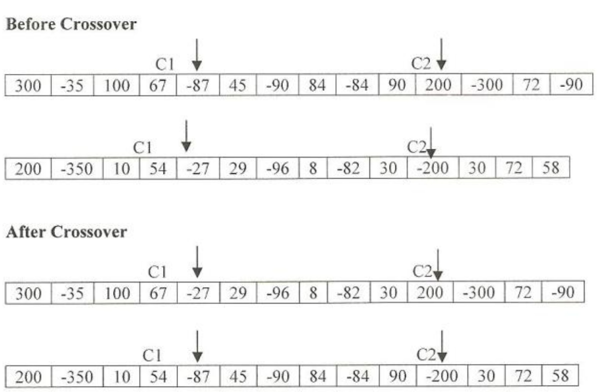

Fig. 4 Chromosomes subjected to two point crossover operation

4.3.3 Mutation

The crossover operation is succeeded by the final stage of genetic operation known as Mutation. In the mutation, a new chromosome is obtained. This chromosome is totally new from the parent chromosome. The concept behind this is the child chromosome thus obtained will be fitter than the parent chromosome. The performance of mutation operation is shown in Fig. 5.

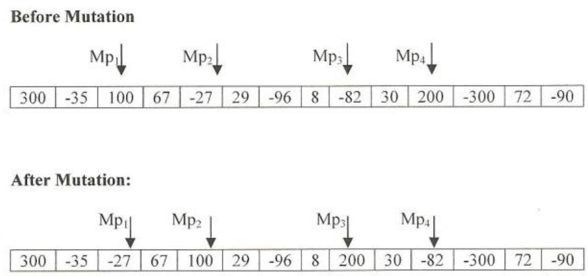

Fig. 5 Chromosome subjected to mutation operation

As in Fig. 5 four mutation points Mp_1, Mp_2, Mp_3 and Mp_4 are chosen. The mutation is done on the particular gene present at the Mutation points. This pointing of gene is done randomly. Hence, the four mutation points may point any of the fourteen genes.
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.

5. Experimental Results

The approach suggested for the optimization of inventory level and thereby efficient supply chain management has been implemented in the platform of MATLAB 7.4. The database consists of the records of stock levels held by each member of the supply chain for every period. For the implementation, 3 different products in circulation in selective manner in the six member supply chain network, are considered.

The sample dataset from a large database which consists of the past records is shown in Table 2.

Table 2 : A sample of data sets having stock levels of different members of the supply chain

F1 P1	F1 P2	F2 P1	F2 P2	F2 P3	F3 P2	F3 P3	D1 P1	D1 P2	D1 P3	A1 P1	A1 P2	A2 P2	A2 P3
120	-368	-62	42	-89	-82	94	-32	-90	-45	-26	-144	162	38
200	-350	10	66	-82	45	-9	40	-84	-35	20	-30	72	-90
96	-352	-68	-25	20	44	-46	-96	-52	-68	-25	25	44	-46
83	-260	96	65	73	24	-75	-44	-28	57	-92	-41	-200	-74
44	-282	77	-26	-14	-100	-74	54	-83	-83	88	-37	76	-63
54	-83	-83	88	-37	76	-63	-37	-73	-29	63	44	75	34
-37	-73	-29	63	44	75	34	-77	-31	62	-69	82	-92	85
-77	-31	62	-69	82	-92	85	35	29	32	-73	35	-56	68
50	108	49	-34	-26	10	-93	84	-72	26	74	68	-42	42
-32	90	-45	60	-144	162	23	77	-39	-52	-79	-92	-87	-50
94	92	-54	30	-17	-52	-50	-12	-68	-60	42	-89	-82	94
122	-66	-62	42	-89	-82	94	23	64	40	10	34	84	-93
23	46	40	108	34	84	-94	21	-84	83	133	-55	-93	-83
48	40	148	85	19	85	-49	-42	63	67	-11	53	107	-44
83	52	-42	-73	-77	83	-33	54	-83	-85	28	-37	76	-65
150	-310	62	-69	-82	42	-8	84	-72	28	74	68	-42	42
210	-360	20	76	-88	55	-15	44	-82	-38	25	-35	78	-95
200	-350	10	66	-82	45	-9	40	-84	-35	20	-30	72	-90
190	-340	10	66	-92	45	-9	50	-84	-35	30	-30	82	-100
200	-370	30	76	-88	55	-20	40	-88	-53	40	-50	72	-90

In the database tabulated in Table 2, the fields are related with the stock levels of particular products that were held by the respective members of the supply chain network. Similarly, different sets of stock levels are held by the database.

As per the proposed analysis based on GA, a random initial chromosome is generated as follows.

Table 3 : Initial Random inventory generated for the GA based analysis

300	-35	100	67	-87	45	-90	84	-84	90	200	-300	72	-90

In this manner two different random chromosomes are generated and they will be subjected to genetic operations like Selection, Crossover and Mutation. An iteration involving all these processes was carried out so as to obtain the best chromosome. For the chosen iteration value of '100', hundred numbers of iterative steps will be performed. The best chromosome obtained as result is depicted in the Table 4.

Table 4: The final best chromosome obtained after the iterations

F1 P1	F1 P2	F2 P1	F2 P2	F2 P3	F3 P2	F3 P3	D1 P1	D1 P2	D1 P3	A1 P1	A1 P2	A2 P2	A2 P3
200	-350	10	66	-82	45	-9	40	-84	-35	20	-30	72	-90

The organization can decide about the quantum of iterations for running the simulation to arrive at the optimal solution. As long as minimization of the fitness function is still possible, then the iteration continues till such a time that no improvement in the fitness function value is noticeable. After a certain number of iterations, if the fitness function value is not improving from the previous iterations, then this is an indication that the fitness function value is stabilizing and the algorithm has converged towards optimal solution. This inference is useful for deciding the number of iterations for running the GA simulation as well as this may be used as the stopping criteria for the algorithm. For greater accuracy, the number of iterations should be sufficiently increased and run on the most frequently updated large database of past records.

The final chromosome obtained from the GA based analysis shown in the Table 4 is the inventory level that has the potential to cause maximum increase of supply chain cost. It is inferred 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. By focusing on the excess/shortage inventory levels and initiating appropriate steps to eliminate the same at each member of the chain, it is possible to optimize the inventory levels in the upcoming period and thus minimize the supply chain cost. That is, the organization should take necessary steps to decrease the production of product 1 in the factory 1 by 200 units to make up for the predicted excess and to increase the production of product 2 in the factory 1 by 350 units to make up for the predicted shortage. Similarly factory 2 should decrease the production of product 1 and product 2 in the factory 2 by 10 units and 66 units respectively to make up for the predicted excess and increase the production of product 3 in the factory 2 by 82 units to make up for the predicted shortage. Factory 3 should decrease the production of product 2 in the factory 3 by 45 units and increase the production of product 3 in the factory 3 by 9 units to make up for the predicted excess / shortage respectively.

The distribution centre 1 should decrease the inventory level of product 1 by 40 units to make up for the predicted excess and increase the inventory level of product 2 by 84 units and product 3 by 35 units to make up for the predicted shortage.

Agent 1 should decrease the inventory level of product 1 by 20 units and increase the inventory level of product 2 by 30 units to make up for the predicted excess / shortage.

Agent 2 should decrease the inventory level of product 2 by 72 units and increase the inventory level of product 3 by 90 units to make up for the predicted excess / shortage.

The analysis extracts an inventory level that made a remarkable contribution towards the increase of supply chain cost, and in turn enabled to predict the future optimal inventory levels to be maintained in all the supply chain members with the aid of these levels. Therefore it is possible to minimize the supply chain cost by maintaining the optimal stock levels that was predicted from the inventory analysis, and thus making the inventory management more effective and efficient.

6. Conclusion

Inventory management is an important component of supply chain management. An innovative and efficient methodology that uses Genetic Algorithms to precisely 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 minimal is proposed. The optimized stock level at all members of the supply chain is obtained by following the proposed genetic algorithm. The complexity of increasing the number of products produced by the number of factories through the supply chain has also been resolved by the proposed approach. The products due to which the members of the supply chain incurred extra holding or shortage cost are determined. More specifically, the inventory is optimized in the whole supply chain regardless of the number of products and the number of members in the supply chain. The proposed approach of inventory management has achieved the objective of minimizing total supply chain cost and has determined the products due to which either additional holding cost or shortage cost is endured.

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