

GENETIC ALGORITHM MODEL FOR MULTI PRODUCT FLEXIBLE SUPPLY CHAIN INVENTORY OPTIMIZATION INVOLVING LEAD TIME

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***Abstract:** Efficient and effective management of inventory throughout the supply chain significantly improves the ultimate service provided to the customer. Efficient inventory management is a complex process which entails the management of the inventory in the whole supply chain. The dynamic nature of the excess stock level and shortage level over all the periods is a serious issue when implementation is considered. In addition, consideration of a factory manufacturing the multiple product leads to very complex inventory management process. The complexity of the problem increases when lead times of stocks and raw materials are involved. In this paper, these issues of inventory management have been focused and a novel approach based on Genetic Algorithm has been proposed in which the most probable excess stock level and shortage level required for inventory optimization in the supply chain is distinctively determined so as to achieve minimum total supply chain cost.*

Keywords: Supply Chain Management, Inventory Optimization, Genetic Algorithm, Flexible operations and supply chain

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1. INTRODUCTION

Global competition, shorter product life cycles, dynamic changes of demand patterns and product varieties and environmental standards cause remarkable changes in the market scenario thereby forcing the manufacturing enterprises to deliver their best in order to strive [1]. Decrease in lead times and expenses, enrichment of customer service levels and advanced product quality are the characteristics that determine the competitiveness of a company in the contemporary market place [4]. The above mentioned factors have made the business enterprises to contemplate about their supply chains. An ensemble of organizations providing products and services to the market may be called as a supply chain. The effective management of the supply chain has become unavoidable these days due to the firm increase in customer service levels [3]. The supply chain cost was immensely influenced by the overload or shortage of inventories. Thus inventory optimization has transpired into one of the most recent topics as far as supply chain management is considered [2], [5], [6].

In this paper, a novel and efficient approach using Genetic Algorithm has been developed for multi-product flexible supply chain inventory optimization . This paper supplements the supply chain inventory optimization analysis without raw material and product lead time considerations [7]. As the lead time plays vital role in the increase of supply chain cost, the complexity in predicting the optimal stock levels increases. In order to minimize the total supply chain cost, the proposed approach clearly determines the most probable excess stock level and shortage level that are required for inventory optimization in the supply chain. In practice, the dynamic nature of the excess stock level and shortage level over all the periods is the typical problem occurring in inventory management. The proposed approach of genetic algorithm predicts the emerging excess/shortage stock levels for the ensuing period by considering the stock levels of the past years, which is an essential information for supply chain inventory optimization as well as total supply chain cost minimization.

2. METHOD AND METHODOLOGY

The proposed method uses the Genetic Algorithm to analyze the stock level that needs essential inventory control. 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 the exemplary supply chain model consists of a 4- stage supply chain having 7 members as depicted in figure 1.

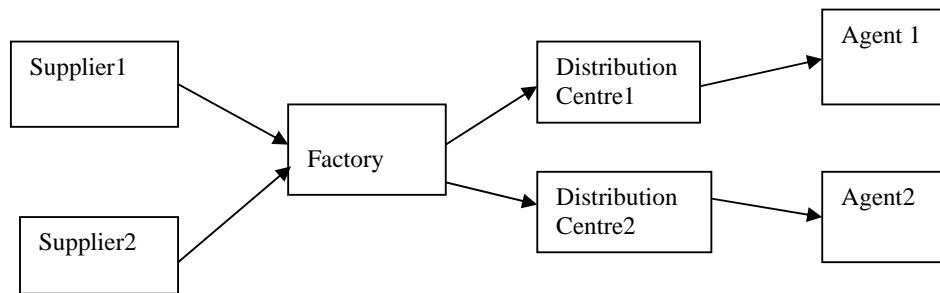


Figure 1: 4 stage-7 member supply chain

As illustrated in figure 1, the factory is the parent of the chain producing two products p_1, p_2 and it is having two distribution centers Distribution center 1 and Distribution center 2, each having an agent. From the distribution center, the respective stocks will be moved to the corresponding agents.

The methodology flow as illustrated in figure 2 is intended to determine the emerging excess or shortage amount of stock levels of the product at different members of the supply chain by analyzing the past records very effectively and thus facilitating efficient inventory management in order to minimize supply chain cost. The analysis flow is initiated by the selection of valid records. In the valid record set selection, records having nil values are neglected and the records having positive or negative values are selected for the analysis using clustering algorithm.

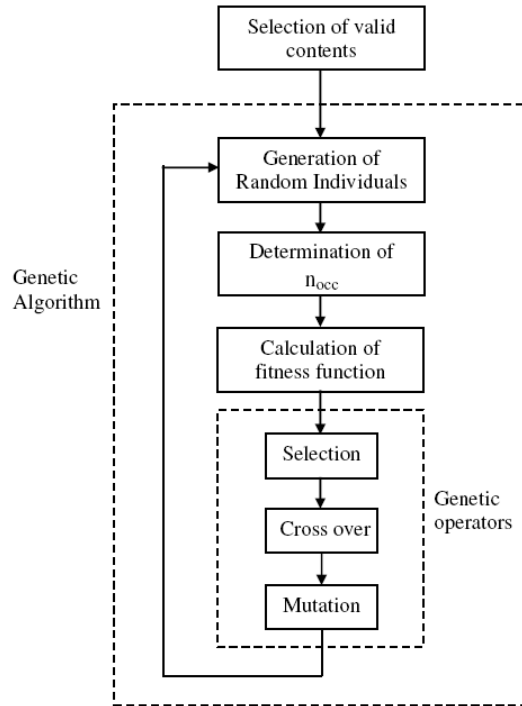


Figure 2: Genetic Algorithm flow for the proposed inventory management analysis

2.1 Generation of Individuals

A random individual generated along with the product representation for various members of the chain is illustrated in figure 3.

	Factory Agent 1		Distribution center1 Agent2		Distribution center2		
	p1	p2	p1	p2	p1	p2	
p1	100	-50	36	25	48	23	-
p2	79	100	-200	289			

Figure 3: The dataset format for the representation of a chromosome

In figure 3, the stock levels of the product at each member is represented with positive values representing excess stock levels of the product and the negative values representing shortage level of the product.

The database holds the information about the stock levels of products in each of the supply chain member, lead time of products in each supply chain member. For l members from factory to end-level-Agents, there are $l-1$ lead times for a particular product and these times are collected from the past records.. Each and every dataset recorded in the database is indexed by a Transportation Identification (TID). For p periods, the TID will be $\{T_1, T_2, T_3, \dots, T_p\}$.

Then each individual is queried into the database for obtaining the details regarding the TID and frequency of the individual. This will bring T_i and $P(\text{occ})$, number of periods of occurrence of that particular individual. This TID will be used as an index in mining the lead time information. After all these queries, the lead time of stocks is obtained as follows

$$T_s = [t_1 \quad t_2 \quad \dots \quad t_{l-1}] \quad (5)$$

And the lead time for raw materials is obtained as

$$T_r = [t_1 \quad t_2 \quad \dots \quad t_r] \quad (6)$$

where, r is the number of raw materials required for the product.

Then, for each individual the evaluation function is calculated.

2.2 Determination of Evaluation function

The evaluation function is determined for each randomly generated individual. The function is given by

$$f(a) = w_1 \left(1 - \frac{P(\text{occ})}{T(\text{periods})} \right) + \log(w_2 \cdot t_{\text{stock}} + w_3 \cdot t_{\text{raw}}) \quad (7)$$

where $a=1,2,3,\dots,m$

$P(\text{occ})$ is the number of counts of past records that occurs throughout the period.

$T(\text{periods})$ is the total number of periods of records in database.

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

In equation (7), w_1 , w_2 and w_3 are the weightings of the factors, stock levels, lead time of stocks and lead time of raw materials in optimization, respectively and they are determined as

$$w_1 = \frac{R_1}{R_1 + R_2 + R_3} \quad (8.1)$$

$$w_2 = \frac{R_2}{R_1 + R_2 + R_3} \quad (8.2)$$

$$w_3 = \frac{R_3}{R_1 + R_2 + R_3} \quad (8.3)$$

R_1 , R_2 and R_3 are the priority levels of influence of stock levels, lead time of stocks and lead time of raw materials in optimization respectively. Increasing the priority level of a factor increases the influence of the corresponding factor in the evaluation function. Hence this R_1 , R_2 and R_3 decide the amount of influence of the factors. The lead time of the stocks t_{stock} is determined as follows

$$t_{\text{stock}} = \sum_{i=1}^{l-1} t_i \quad (9)$$

And the lead time required to fill the raw materials is given as

$$t_{\text{raw}} = \sum_{i=1}^r t_i \quad (10)$$

When the values of t_{stock} and t_{raw} from equation (9) and (10) are substituted in the equation (7), it gives an evaluation value for each individual.

The fitness function is carried out for each chromosome and the chromosomes are sorted on the basis of the result of the fitness function.

In the fitness function, the ratio $(P(\text{occ}) / T(\text{periods}))$ plays the role of finding the probability of occurrence of a particular chromosome; and $[1 - (P(\text{occ}) / T(\text{periods}))]$ will ensure minimum value corresponding to the maximum probability; t_{stock} will find the total lead time of stocks and t_{raw} will find the total lead time of raw materials in optimization respectively for the chosen record.

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.

2.3 Genetic operations

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

2.3.1. 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 assigning ranks based on the calculated fitness value to each of the prevailing chromosome. On the basis of this ranking, best chromosome is selected for further processing. The chromosome generating value as minimum as possible will be selected by the fitness function since the objective is to minimize the inventory levels and lead times.

2.3.2. Crossover:

Among the numerous crossover operators in practice, for our complex operation, we have chosen two point crossover. From the mating pool, two chromosomes are subjected for the two point crossover. The crossover operation performed in our analysis is illustrated in figure 4 and 5.

Before Crossover:

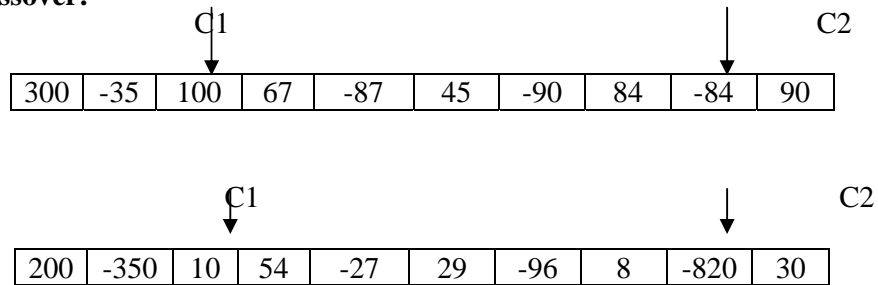


Figure 4: Chromosomes before 2- point Crossover

After Crossover:

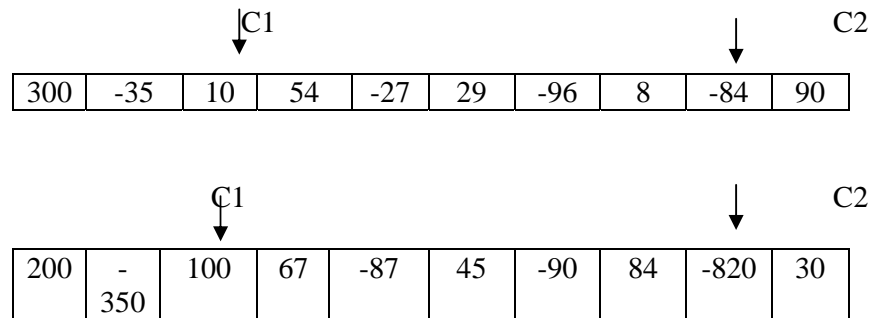


Figure 5: Chromosomes after 2- point Crossover

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.

2.3.3. Mutation:

3 IMPLEMENTATION RESULTS

The analysis based on GA for optimal inventory control is implemented in the platform of MATLAB (version 7.4) using relevant past records in the format of Table 1 and Table 2 which contain sample data of past records.

Table 1. Sample data from database of different stock levels

TI	FP1	FP2	D1P1	D1P2	D2P1	D2P2	A1P1	A1P2	A2P1	A2P2
1	-12	-68	20	42	-91	-24	41	-32	02	50
2	-07	37	-81	-64	-31	99	-196	-146	-4	43
3	-12	-86	-20	42	91	24	41	-32	02	-40
4	-07	37	-81	-64	-31	99	-196	-146	-4	43
5	-07	37	-81	-64	-31	99	-16	-146	-4	43

Table 1 is having the Transportation ID, the stock levels which are in excess or in shortage at each supply chain member. The transportation ID mentioned in table is used as an index in extracting the lead times for movements of stocks .

Table 2. Sample data from Database which is having lead times for stocks

TI	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
1	2	4	5	1	4	6	2	4	6	5
2	4	5	2	4	1	6	7	2	3	3
3	3	5	2	8	5	7	9	6	8	7
4	4	6	2	7	9	10	3	8	2	8
5	3	4	5	10	4	6	12	3	9	6

Table 2 depicts the sample data which is having the transportation ID and the lead times for stocks between the supply chain members.

Here T1 is the lead time from S1 to F

T2 is the lead time from S2 to F

T3 is the lead time of product1 from F to D1

T4 is the lead time of product2 from F to D1

T5 is the lead time of product1 from F to D2

T6 is the lead time of product2 from F to D2

T7 is the lead time of product1 from D1 to A1

T8 is the lead time of product2 from D1 to A1

T9 is the lead time of product1 from D2 to A2

T10 is the lead time of product2 from D2 to A2

Table 3 describes two random individuals generated initially.

Table 3. Initial random individuals

FP1	FP2	D1P1	D1P2	D2P1	D2P2	A1P1	A1P2	A2P1	A2P2
300	-35	100	67	-87	45	-90	84	-84	90
200	-350	10	54	-27	29	-96	8	-820	30

The simulation run on a large database of past records showing Fitness function improvement at different levels of iteration is as follows:

Simulation Result of GA showing Fitness function improvement with

$$w1 = 0.6250; w2 = 0.3125; w3 = 0.0625 ;$$

For iteration 20: fitness = 5.7845

For iteration 50; fitness = 5.6450; Improvement: 2%

For iteration 70; fitness = 5.3749; Improvement: 5%

For iteration 100; fitness = 4.8220; Improvement: 10%

As for deciding the total number of iterations required, the criteria followed is that 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. For greater accuracy, the number of iterations should be sufficiently increased and run on the most frequently updated large database of past records.

The best chromosome obtained as result after satisfying the above mentioned convergence criteria is depicted in the Figure 8.

200	-350	10	66	-120	46	-9	40	-8	20
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Figure 8: The final best chromosome obtained from the analysis

The final individual thus obtained represents the emerging excess or shortage stock levels at each of the seven members providing essential information for supply chain inventory optimization.

This final chromosome obtained from the GA based analysis shown in the figure 8 is the inventory level that has the potential to cause maximum increase of supply chain cost including lead time considerations. By taking necessary steps to eliminate the identified emerging excesses/ shortages at different members of the supply chain, the supply chain cost can be minimized to that extent. Thus by following the predicted stock levels, we can avoid the increase of supply chain cost.

4. CONCLUSION

Inventory management is an important component of supply chain management. The members of the supply chain are responsible for minimizing the costs of a supply chain by managing inventory levels in a number of production and distribution operations associated with different chain stages. As the lead time plays vital role in the increase of supply chain cost, the complexity in predicting the optimal stock levels increases. We have proposed an innovative and efficient methodology that uses Genetic algorithm presented that is aimed at reducing the total supply chain cost as it undoubtedly established the most probable surplus stock level and shortage level along with the consideration of lead time involved in supplying the stocks that are required for inventory optimization in the supply chain such that the total supply chain cost is minimal. The proposed approach was implemented and its performance was evaluated using MATLAB 7.4. The performance of Genetic Algorithm was well as predicted. By following the proposed genetic algorithm based approach for inventory management, we determined the products due to which the members of the supply chain incurred extra holding or shortage cost in the whole supply chain. The proposed approach of inventory management has achieved the objectives which are the minimization of total supply chain cost as well as lead time and the determination of the products due to which the respective supply chain members endured either additional holding cost or shortage cost with lead time consideration which is a vital information for supply chain inventory optimization.

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