Article

A supply chain management of chemical industry for deteriorating items with warehouse using genetic algorithm

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Abstract
This study discussed the supply chain inventory optimization of chemical industry and genetic algorithm for deteriorating items in a manufacture of chemical industry, warehouse of chemical industry, three distribution centers of chemical industry, and three retailer's of chemical industry environment using genetic algorithm. Demand is assumed to be known and constant. Shortages of chemical industry are not allowed and apply inflation of chemical industry. A warehouse of chemical industry is used to store the excess units over the fixed capacity of the two distribution centers of chemical industry. Further supply chain inventory optimization of chemical industry and genetic algorithm optimization dispatching policies was investigated in different scenarios in the model.

Keywords supply chain of chemical industry; inventory optimization of chemical industry; warehouse of chemical industry; retailer's of chemical industry; distribution centers of chemical industry; genetic algorithm.

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1 Introduction

Inventory control, otherwise known as stock control, is used to show how much stock have to maid available at any time, and how tracks are kept for it. It applies to every item that uses to produce a product or service, from raw materials to finished goods. It covers stock at every stage of the production process, from purchase and delivery to using and re-ordering the stock. Efficient stock control allows an organization/industry/company to have the right amount of stock in the right place at the right time. It ensures that capital is not tied up unnecessarily, and protects production if problems arise with the supply chain. Inventory control is the techniques of maintaining stock-items at desired levels. The purpose of all inventory models is to minimize inventory costs. As a result of the inventory model, a designer of air-condition machine decided to redesign its old model machine to enhance its working efficiency and reduce inventory costs in meeting a global market for its air-condition machines.

Inventory is held throughout the supply chain in the form of raw materials, work in process and finished goods. Inventory exists in the supply chain because of a mismatch between supply and demand. This mismatch is intentional at a manufacturer, where it is economical to manufacture in large lots that are then stored for future sales. The mismatch is also intentional at a retail store where inventory is held in anticipation of future demand. Inventory is a major source of cost in a supply chain and has a huge impact on responsiveness. An important role that inventory plays in the supply chain is (1) to increase the amount of demand that can be satisfied by having the product ready and available when the customer wants it. (2) To reduce cost by exploiting economics of scale that may exist during production and distribution. (3) To support a firm’s competitive strategy. If a firm’s competitive strategy requires very high level of responsiveness, a company can achieve this responsiveness by locating large amounts of inventory close to a customer. Conversely, a company can also use inventory to become more efficient by reducing inventory through centralized stocking.

Discussions so far were limited to genetic algorithm (GA; Zhang, 2014, 2016) that handled the optimization of a single parameter. The optimization criteria are represented by fitness functions and are used to lead towards an acceptable solution. A typical single objective optimization problem is the TSP. There the sole optimization criterion is the cost of the tour undertaken by the salesperson and this cost is to be minimized. However, in real life we often face problem which require simultaneous optimization of several criteria. For example, in VLSI circuit design the critical parameters are chip area power consumption delay fault tolerance etc. While designing a VLSI circuit the designer may like to minimize area power consumption and delay while at the same time would like to maximize fault tolerance. The problem gets more complicated when the optimizing criteria are conflicting. For instance an attempt to design low-power VLSI circuit may affect its fault tolerance capacity adversely. Such problems are known as multi-objective optimization (MOO) (Ferrarini, 2012; Zhang et al., 2017). Multi-objective optimization is the process of systematically and simultaneously optimizing a number of objective functions. Multiple objective problems usually have conflicting objectives which prevents simultaneous optimization of each objective. As GAs are population based optimization processes they are inherently suited to solve MOO problem. However traditional GAs are to be customized to accommodate such problem. This is achieved by using specialized fitness functions as well as incorporating methods promoting solution diversity. Rest of this section presents the features of multi-objective GAs.

2 Related Works

Narmadha at al. (2010) proposed the multi-product inventory optimization using uniform crossover genetic algorithm. Radhakrishnan et al. (2009) gave an inventory optimization in Supply Chain Management using genetic algorithm. Singh and Kumar (2011) gave an inventory optimization in Efficient Supply Chain Management. Priya and Iyakutti (2011) proposed a web based multi product inventory optimization using genetic algorithm. Thakur and Desai (2013) made the inventory analysis using genetic algorithm in supply chain management. Khalifehzadeh et al. (2015) presented a four-echelon supply chain network design with shortage. Kannan et al. (2010) discussed a genetic algorithm approach for solving a closed loop supply chain model. Jawahar and Balaji (2009) proposed a genetic algorithm for the two-stage supply chain distribution problem associated with a fixed charge. Zhang et al. (2013) presented a modified multi-criterion optimization genetic algorithm for order distribution in collaborative supply chain. Che and Chiang (2010) proposed a modified Pareto genetic algorithm for multi-objective build-to-order supply chain planning with product assembly. Yimer and Demirli (2010) presented a genetic approach to two-phase optimization of dynamic supply chain scheduling. Wang et al. (2011) proposed location and allocation decisions in a two-echelon supply chain with stochastic demand. Humphreys et al. (2009) reduced the negative effects of sales promotions in supply chains using genetic algorithms. Sherman et al. (2010) gave a production modelling with genetic algorithms for a stationary pre-cast supply chain. Ye et al. (2010) proposed some improvements on adaptive genetic algorithms for reliability-related applications. Guchhait et al. (2010) presented multi-item inventory model of breakable items with stock-dependent demand under stock and time dependent breakability rate. Changdar et al. (2015) gave an improved genetic algorithm based approach to solve constrained knapsack problem in fuzzy environment. Sourirajan et al. (2009) presented a genetic algorithm for a single product network design model with lead time and safety stock considerations. Jiang et al. (2015) gave the joint optimization of preventive maintenance and inventory policies for multi-unit systems subject to deteriorating spare part inventory. Dey et al. (2008) proposed two storage inventory problem with dynamic demand and interval valued lead-time over finite time horizon under inflation and time-value of money. Jawahar and Balaji (2012) proposed a genetic algorithm based heuristic to the multi-period fixed charge distribution problem. Pasandideh et al. (2010) gave a parameter-tuned genetic algorithm for multi-product economic production quantity model with space constraint, discrete delivery orders and shortages. Yadav et al. (2016) proposed a cooperative two-warehouse inventory model for deteriorating items with variable holding cost, time-dependent demand and shortages. Singh et al. (2016) proposed a two-warehouse model for deteriorating items with holding cost under particle swarm optimization. consider a similar model. Yadav et al. (2016) analyzed a multi objective optimization for electronic component inventory model & deteriorating items with two-warehouse using genetic algorithm. Sharma et al. (2016) focused an optimal ordering policy for non-instantaneous deteriorating items with conditionally permissible delay in payment under two storage management. Yadav et al. (2016) analyzed genetic algorithm and particle swarm optimization for warehouse with supply chain management in inventory control.

3 Assumptions and Notations

3.1 Assumptions

1. The production rate is $\omega_1 t_i$ are linear function of time.
2. The demand rate is $D_1 t_i$ are linear function of time.
3. The holding cost is Ht_i are linear function of time.

3.2 Notations

θ_1 = Scale parameter of amelioration rate.
θ_2 = Shape parameter of amelioration rate.
$\alpha_{RM} + 2$ = Raw material's of chemical industry Scale parameter for the deterioration rate.
$\beta_{RM} + 1$ = Raw material's of chemical industry Shape parameter for the deterioration rate.
$\alpha_S + 2$ = Storage Scale of chemical industry parameter for the deterioration rate.
$\beta_S + 1$ = Storage Shape of chemical industry parameter for the deterioration rate.
$\alpha_M + 2$ = Manufacturing of chemical industry Scale parameter for the deterioration rate.
$\beta_M + 1$ = Manufacturing of chemical industry Shape parameter for the deterioration rate.
$\alpha_W + 2$ = Warehouse of chemical industry cale parameter for the deterioration rate.
$\beta_W + 1$ = Warehouse of chemical industry Shape parameter for the deterioration rate.
$\alpha_{DC} + 2 = D.C - 1$ of chemical industry Scale parameter for the deterioration rate.
$\beta_{DC} + 1 = D.C - 1$ of chemical industry Shape parameter for the deterioration rate.

$\alpha_R + 2$ = Retailer's − 1 of chemical industry Scale parameter for the deterioration rate.
$\beta_R + 1$ = Retailer's − 1 of chemical industry Shape parameter for the deterioration rate.
$I_{Ri}(t_i)$ = Raw material'sof chemical industry inventory level
$I_{Si}(t_i)$ = Storageof chemical industry inventory level .
$I_{Mi}(t_i)$ = Manufacturingof chemical industry finished goods inventory level .
$I_{Wi}(t_i)$ = Warehouse of chemical industry finished goods inventory level .
$I_{DCi}(t_i)$ = Distributor center of chemical industry finished goods inventory level .
$I_{Ri}(t_i)$ = Retailer's of chemical industry finished goods inventory level .
TC_{RM} = Raw material's of chemical industry net present total cost per unit time.
TC_S = Storage of chemical industrynet present total cost per unit time.
TC_M = Manufacturing of chemical industry net present total cost per unit time.
TC_W = Warehouse of chemical industry net present total cost per unit time.
TC_{DC_i} = Distributor center of chemical industrynet present total cost per unit time.
TC_{R_i} = Retailer's of chemical industry net present total cost per unit time.

4 Mathematics Model in Supply Chain Inventory Control

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 of chemical industry effective. For this purpose, we are using Economic Load Dispatch algorithm method as assistance. In practice, the supply chain is of length m, means having m number of members in supply chain of chemical industry such as Raw material of chemical industry, Storage of chemical industry, Manufacture of chemical industry, warehouse of chemical industry, Distribution centers of chemical industry, Distribution Center-1 of chemical industry. Each distribution center of chemical industry further comprises of several Retailer's but as stated in the example case, each Distribution center of chemical industry is having one agent. So, in aggregate there are Retailers' of chemical industry, Retailer's-1 of chemical industry for Distribution Center-1 of chemical industry so on. Here, for instance we are going to use a Supply Chain of chemical industry, as illustrated in the Fig 1.

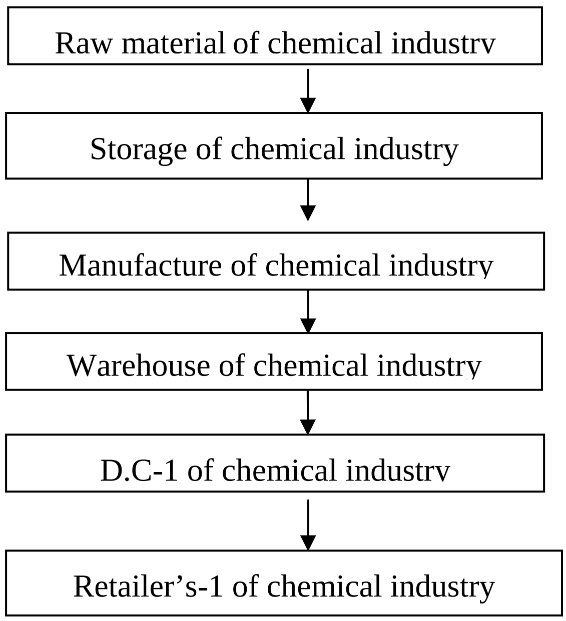

Fig. 1 A supply chain of chemical industry.

4.1 Raw materials of chemical industry

$$TC_{RM}=\left[\frac{1}{T}\left[\sum_{t_1=0}^{T_1}\left\{\begin{array}{l}\left[\theta_1\theta_2 t_1^{\theta_2-1}I_{RM}(t_1)-(\alpha_{RM}+2)(\beta_{RM}+1)t_1^{\beta RM}I_{RM}(t_1)\right]+\left(R_0t_1\right)\\+\left[Ht_1\{\theta_1\theta_2 t_1^{\theta_2-1}I_{RM}(t_1)-(\alpha_{RM}+2)(\beta_{RM}+1)t_1^{\beta R}I_R(t_1)\}\right]\end{array}\right\}\right]\right] \quad (1)$$

4.2 Storage of chemical industry

$$TC_S=\left[\frac{1}{T}\left[\sum_{t_2=0}^{T_2}\left\{\begin{array}{l}\left[(D_1t_2)-(\alpha_S+2)(\beta_S+1)t_2^{\beta S}I_S(t_2)\right]+\left(S_0t_2\right)\\+\left[Ht_2\left\{(D_1t_2)-(\alpha_S+2)(\beta_S+1)t_2^{\beta S}I_S(t_2)\right\}\right]\end{array}\right\}\right]\right] \quad (2)$$

4.3 Manufacturing of chemical industry

$$TC_M=\left[\frac{1}{T}\left[\sum_{t_3=0}^{T_3}\left\{\begin{array}{l}\left[\omega_1t_3-D_1t_3-(\alpha_M+2)(\beta_M+1)t_3^{\beta M}I_M(t_3)\right]+\left(M_0t_3\right)\\+\left[Ht_3\left\{\omega_1t_3-D_1t_3-(\alpha_M+2)(\beta_M+1)t_3^{\beta M}I_M(t_3)\right\}\right]\end{array}\right\}\right]\right] \quad (3)$$

4.4 Warehouse of chemical industry:

$$TC_W=\left[\frac{1}{T}\left[\sum_{t_4=0}^{T_4}\left\{\begin{array}{l}\left[\omega_1t_4-D_1t_4-(\alpha_W+2)(\beta_W+1)t_4^{\beta W}I_M(t_4)\right]+\left(W_0t_4\right)\\+\left[Ht_4\left\{\omega_1t_4-D_1t_4-(\alpha_4+2)(\beta_W+1)t_4^{\beta W-1}I_M(t_4)\right\}\right]\end{array}\right\}\right]\right] \quad (4)$$

4.5 Distributor center-1 of chemical industry

$$TC_{DC_1}=\left[\frac{1}{T}\left[\sum_{t_5=0}^{T_5}\left\{\begin{array}{l}\left[\omega_1t_5-D_1t_5-(\alpha_5+2)(\beta_{DC}+1)t_5^{\beta DC}I_{DC}(t_5)\right]+\left(C_0t_5\right)\\+\left[Ht_5\left\{\omega_1t_5-D_1t_5-(\alpha_5+2)(\beta_{DC}+1)t_5^{\beta DC}I_{DC_1}(t_5)\right\}\right]\end{array}\right\}\right]\right] \quad (5)$$

4.6 Retailer's of chemical industry

$$TC_R=\left[\frac{1}{T}\left[\sum_{t_6=0}^{T6}\left\{\begin{array}{l}\left[-D_1t_6-(\alpha_6+2)(\beta_R+1)t_6^{\beta R}I_R(t_6)\right]+\left(Rt_6\right)\\+\left[Ht_6\left\{-D_1t_6-(\alpha_6+2)(\beta_R+1)t_6^{\beta R}I_R(t_6)\right\}\right]\end{array}\right\}\right]\right] \quad (6)$$

$$TC=\left[\frac{TC_{RM}+TC_S+TC_M+TC_W+TC_{DC}+TC_R}{T}\right] \quad (7)$$

$$TC = \left[\frac{1}{T} \left\{ \begin{array}{l} \left[\sum_{t_1=0}^{T_1} \left\{ \begin{array}{l} \left[\theta_1\theta_2 t_1^{\theta_2-1} I_{RM}(t_1) - (\alpha_{RM}+2)(\beta_{RM}+1) t_1^{\beta RM} I_{RM}(t_1) \right] + \left(R_0 t_1 \right) \\ + \left[Ht_1 \{ \theta_1\theta_2 t_1^{\theta_2-1} I_{RM}(t_1) - (\alpha_{RM}+2)(\beta_{RM}+1) t_1^{\beta R} I_R(t_1) \} \right] \end{array} \right\} \right] + \\ \left[\sum_{t_2=0}^{T_2} \left\{ \begin{array}{l} \left[(D_1 t_2) - (\alpha_S+2)(\beta_S+1) t_2^{\beta S} I_S(t_2) \right] + \left(S_0 t_2 \right) \\ + \left[Ht_2 \left\{ (D_1 t_2) - (\alpha_S+2)(\beta_S+1) t_2^{\beta S} I_S(t_2) \right\} \right] \end{array} \right\} \right] + \\ \left[\sum_{t_3=0}^{T_3} \left\{ \begin{array}{l} \left[\omega_1 t_3 - D_1 t_3 - (\alpha_M+2)(\beta_M+1) t_3^{\beta M} I_M(t_3) \right] + \left(M_0 t_3 \right) \\ + \left[Ht_3 \left\{ \omega_1 t_3 - D_1 t_3 - (\alpha_M+2)(\beta_M+1) t_3^{\beta M} I_M(t_3) \right\} \right] \end{array} \right\} \right] + \\ \left[\sum_{t_4=0}^{T_4} \left\{ \begin{array}{l} \left[\omega_1 t_4 - D_1 t_4 - (\alpha_W+2)(\beta_W+1) t_4^{\beta W} I_M(t_4) \right] + \left(W_0 t_4 \right) \\ + \left[Ht_4 \left\{ \omega_1 t_4 - D_1 t_4 - (\alpha_4+2)(\beta_W+1) t_4^{\beta W-1} I_M(t_4) \right\} \right] \end{array} \right\} \right] + \\ \left[\sum_{t_5=0}^{T_5} \left\{ \begin{array}{l} \left[\omega_1 t_5 - D_1 t_5 - (\alpha_5+2)(\beta_{DC}+1) t_5^{\beta DC} I_{DC}(t_5) \right] + \left(C_0 t_5 \right) \\ + \left[Ht_5 \left\{ \omega_1 t_5 - D_1 t_5 - (\alpha_5+2)(\beta_{DC}+1) t_5^{\beta DC} I_{DC_1}(t_5) \right\} \right] \end{array} \right\} \right] + \\ \left[\sum_{t_6=0}^{T6} \left\{ \begin{array}{l} \left[-D_1 t_6 - (\alpha_6+2)(\beta_R+1) t_6^{\beta R} I_R(t_6) \right] + \left(Rt_6 \right) \\ + \left[Ht_6 \left\{ -D_1 t_6 - (\alpha_6+2)(\beta_R+1) t_6^{\beta R} I_R(t_6) \right\} \right] \end{array} \right\} \right] \end{array} \right\} \right] \quad (8)$$

5 Genetic Algorithm Model in Supply Chain Inventory Control

Which depicts the steps applied for the optimization analysis. 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.

5.1 Chromosome

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. Since a 10 member supply chain is used for illustration, the length of the chromosome n is 10, i.e. 10 genes. And the chromosome representation is pictured in Fig. 2. Each gene of the chromosome is representing the amount of stock that is in excess or in shortage at the respective members of the supply chain.

Chromosome 1

7700	7600	7550	-7400	7600	-7450	7450	7500	7400	-7250

Chromosome 2

7700	7650	7500	7450	7400	-7350	-7450	-7400	7550	7650

Fig. 2 Random individual generated for the genetic operation.

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/ repetitions of the particular amount of stock level for the ten members M_P that are going to be used further in the fitness function.

5.2 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.

5.3 Fitness

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.

$$U(i) = \log\left(1 - \frac{M_P}{M_q}\right) \quad i = 1,2,3,4,5,6,7LL, n$$

Where, M_P is the number of counts that occurs throughout the period, M_q is the total number of inventory values obtained after clustering, n 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.

5.4 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 Fig. 3.

Before Crossover

7700	7500	7550	-7400	7600	-7350	7450	7500	-7580	7480
7770	7550	7500	7550	7700	-7350	-7550	-7700	-7680	7650

After Crossover

7600	7700	7450	-7300	-7550	7370	-7570	7350	7350	-7540
7670	7650	7500	-7320	7620	-7480	7560	-7400	7610	-7580

Fig. 3 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.

5.5 Mutation

The newly obtained chromosomes from crossover operation are then pushed for mutation. By performing mutation, a new chromosome will be generated as illustrated below (Fig. 4).

Before Mutation

7570	7650	7800	-7320	7420	-7380	7360	-7500	7350	-7270

After Mutation

7570	7650	7800	7400	-7440	7490	-7370	7400	7390	-7250

Fig. 4 Chromosomes subjected to operation.

This is done by random generation of two points and then performing swaps between both the genes.

6 Conclusion

In this paper an integrated production of chemical industry supply chain inventory model of chemical industry with linear production of chemical industry and demand rate of chemical industry was developed for deteriorating item and economic load dispatch using genetic algorithm is a significant component of supply chain management of chemical industry. In this model the deterioration, the multiple deliveries and the time discounting are considered from the perspective of Supply Chain of chemical industry, Raw material of chemical industry, Storage of chemical industry, Manufacture of chemical industry, warehouse of chemical industry, three distribution centers of chemical industry as well as three Retailer's of chemical industry using genetic algorithm and MATLAB.

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