Genetic Algorithm Approach for Optimization in a Multi Objective Supply Chain Network

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Abstract: In recent years supply chain has become increasingly global in nature. Increased competition has driven the need for more efficient and cost-effective supply chain strategies and production methods. Proper supply chain management can reduce cost, improve service level and customer satisfaction as well as optimize transportation system. This research proposes a multi-objective model to find the optimal solution of total cost including transportation cost in different stages as well as holding cost and minimize time (Earliness & Tardiness) of distribution center. Authors consider some constraints like amount of products sent to retailers is within the capacity of the distribution centers capacity, customer satisfaction, supplier’s capacity, supplier’s capacity on production of products, plants capacity for each product and the last one is all the variables must be positive. Using Genetic Algorithms approach with the help of MATLAB; all the values of variables and objective functions were found. Many companies realize that coordinating proper supply chain activities can maximize the performance and profit. So the proposed model is composed of multi objective function to minimize the total cost including transportation cost between supplier, plant, distribution center & customer and as well as minimize time in distribution center.

1. Introduction

The supply chain is a complex network from suppliers to customers, which involves people, technologies, activities, information and resources. Its design and management has the purpose of obtaining the best global performances under specific operating criteria [1].

This research specifically deals with the total cost optimization of a four-stage supply chain network and time optimization in distribution center using the Genetic Algorithm. The design of SC networks is a difficult task because of the intrinsic complexity of the major subsystems of these networks and the many interactions among these subsystems, as well as external factors such as the considerable multi objective functions [2].

The decisions range from what product to produce and their design, how much, when and from where to buy a product, how much, where and when to produce a product, etc [3]. Recently there has been a growing interest in research in supply chain network optimization problems. This may be due to increasing competitiveness introduced by rapid globalization such that firms wants to reduce costs and maintain profit margins as observed by [4] or from a practical stand point of view, the rise may be from a number of changes in the manufacturing environment including the rising cost of manufacturing, the shrinking of manufacturing bases, shortened life cycle, the leveling of the playing field within the manufacturing industries and globalization of market economies as suggested by [5] as well as attractive to cost ratios and building of long term relationships with trusted suppliers as stated by [6].

The supply chain network design problem has been optimized as single objective problem [7]; [8]. [9] developed a steady-state mathematical model for SC management by combining strategic and operational design and planning decisions using an iterative solution procedure.

According to the research by [10] formulated cost optimization of supply chain network using genetic algorithm. Select one or more suppliers to order and replenish different types of products in such a way as to minimize the total ordering cost spent by a wholesaler (i.e. the sum of total product cost, and total backorder cost related to lead time), maximize
the savings on different products and find the best sequence for delivering various kinds of products to different retailers in order to minimize the total cost due to the total distance traveled by a vehicle and due to the total time required for a vehicle to serve retailers. GA is adjusting the crossover rate and mutation rate after each ten consecutive generations is suggested as the best way to solve this problem. [11] described cost optimization of supply chain network using genetic algorithm. By comparing the algorithm cost and real cost of manufacturing plant. A genetic algorithm based model was proposed by [12] that covers only 3 key components of a supply chain model. [13] described an analytical model is formulated for the location and allocation of facilities of four-echelon supply chain network for the optimal facility location and capacity allocation decisions. [14] describe the application of Evolutionary Algorithms to the optimization of a simplified supply chain in an integrated production-inventory-distribution system. [15] described in his book on “Multi objective optimization using Evolutionary Algorithm” proposed that Evolutionary multi objective optimization principle of handling multi-objective optimization problem is representative set of Pareto-optimal solutions. [16] explain supply chain two stage distribution inventory optimization model for a distribution network with multiple ware houses supplying multiple retailers, who in turn serve a large number of customers. This model has taken the distribution and inventory carrying costs into account in the supply chain network at each period.

2. Problem Formulation

Author considered a general supply chain network model consisting of supplier, manufacturing plant, distribution centers (DC), and retailer as shown in Figure below. In this research authors have developed a network model for cost optimization as well as time optimization (tardiness and earliness of distribution center) of a supply chain model in an industry which has supplier, manufacturing plant, distribution center and retailer to deliver the finished products to the customer. Cost optimization has been implemented in all four stages which is included transportation cost from Supplier to plants, cost of transporting products from plants to DC, cost of holding products at DC and from DC to retailers. In this model, two objectives have been considered. First one is the cost minimization. Total cost minimization includes cost of buying and transporting raw materials from supplier to plants, cost of transporting products from plants to DC, cost of holding products at DC and from DC to retailers.

The other objective function is about on-time delivery (minimum delay) which involves- earliness: representing the amount of products that are delivered prior to the due date, and tardiness: representing the amount of products that are delivered after their due date.

3. Model Development

3.1 Objective function 1:

- **Minimize the transportation cost between supplier to plants C(1):**
  
  A supplier’s transportation cost consists of the amount of raw material supplied (rsk) and multiplied by unit transportation cost (tsk). The Objective is-
Minimize the transportation cost between plant to DC C (2):
This cost consists of amount of products supplied in DC (fkj) and multiplied by unit transportation cost (ckj).
Minimize C(2) = \sum_{k=1}^{n} \sum_{j=1}^{n} f_{kj} * c_{kj}

Minimize the holding cost of DC C (3):
This cost consists of unit holding cost (hj) and total number of backorders of products at distribution center (bpjt).
Minimize C(3) = \sum_{j=1}^{m} \sum_{t=1}^{n} h_{jt} * b_{pjt}

Minimize the transportation cost between DC and retailer C(4):
This cost consists of unit transportation cost between DC to retailer (rji) and total number of amount supplied in retailer (qji).
Minimize C(4) = \sum_{p=1}^{m} \sum_{t=1}^{n} r_{pi} * q_{ji}

Cost minimization f (1) = C(1)+C(2)+C(3)+C(4)
= \sum_{p=1}^{m} \sum_{t=1}^{n} (r_{sk} * t_{sk} + f_{kj} * c_{kj} + h_{jt} * b_{pjt} + r_{ji} * q_{ji})

3.2 Objective function 2:
This objective function is about on time delivery. This function has two parts.
First part representing the amount of products that are delivered prior to the due date (Zpjt).

Second part representing the amount of products that are delivered after their due date (bpjt).

Time minimization f(2) = \sum_{p=1}^{m} \sum_{t=1}^{n} (z_{pjt} + b_{pjt})

In the proposed model, the following notations are used after reviewing the literature and considering practical situations:
a) Notations for indices of the entities are as follows:
   - s: supplier
   - k: plant
   - j: distributor
   - i: retailer
   - p: product type
   - t: time
b) Variables for quantities are as follows:
   - f_{kj}: Total number of products from plant k to distribution center j
   - q_{ji}: Total number of products from distribution center j to retailer i
   - b_{pjt}: Total number of backorders of products at distribution center j in time t (tardiness)
   - z_{pjt}: Total number of products delivered to distribution center j in time t (earliness)

The variable notation for model parameters are:
   - c_{kj}: Unit transportation cost of products from plant k to distribution center j
   - t_{sk}: Unit transportation cost of raw materials from supplier s to plant k
   - c_{s}: Unit cost of raw material from supplier s
   - h_{jt}: Unit holding cost at distribution center j
   - r_{jt}: Unit transportation cost from distribution center j to retailer i
   - h_{j}: Holding cost of retailer i
   - d_{it}: Quantity of demanded items from retailer i on a given time t.

3.3 Setting Constraints:
a. Amount of products: Total number of products which is delivered from plant to DC is always greater than the products which is delivered from DC to retailer.
f_{kj} \geq q_{ji} : Amount of product sent to retailers is within the capacity of the distribution centers capacity

b. Customer satisfaction: The product which is delivered to the DC to retailer is always greater than the value of customer demand.
q_{ji} \geq d_{it} : Customer satisfaction.

Supplier's capacity:
Capacity of supplier is greater than the amount of raw material which is supplied from supplier to plant.
r_{sk} \leq sc_{s} : Supplier's capacity.

Supplier's capacity on production:
Amount of products from supplier to plants is always greater than the amount of products supplied from plant to DC.
f_{kj} \leq r_{sk} : Supplier's capacity on production of products.

Supplier's capacity on production of products:
Capacity of plant is always greater than the total number of products from plant to DC.
f_{kj} \leq D_{k} : Plant's capacity for each product

All of the variables must be positive.
f_{kj} r_{sk} q_{ji} b_{pjt} z_{pjt} \geq 0
3.4 Applying Genetic Algorithm

![Genetic Algorithm Approach for Optimal Selection](image)

When all the inputs of the process are ready, the final and last step is the application of genetic algorithm. To apply genetic algorithm all the parameters and operators are set which suit the system most and can find the optimum result for the objective functions which implies minimization of the total supply chain cost and time.

4. Data Implementation

### Table 1. Assumed cost data for different stage

<table>
<thead>
<tr>
<th>Transportation Stage</th>
<th>Total Cost (Tk)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supplier to plant</td>
<td>15, 20, 33</td>
</tr>
<tr>
<td>Plant to Distribution center</td>
<td>35, 50, 61</td>
</tr>
<tr>
<td>Distribution center to Retailer</td>
<td>55, 75, 84</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Holding cost stage</th>
<th>Amount (Tk)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distribution center</td>
<td>2, 5, 8</td>
</tr>
</tbody>
</table>

5. Results & Findings

The proposed simple genetic algorithm approach for optimal cost and time with optimum amount of product which supplied from one stage to another stage shows in result. This calculation is briefly shown in appendix. The optimized result is shown in the table 6.1 which is given below. All values are multiplied by 10,000.

4.1 Data Selection

All data was selected randomly from hypothetical chart. The hypothetical data chart is given below.

<table>
<thead>
<tr>
<th>Table 2. Hypothetical Data Chart</th>
</tr>
</thead>
<tbody>
<tr>
<td>520781, 677797, 931401, 190867, 297751</td>
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<tr>
<td>150783, 82286, 872349, 602216, 679356</td>
</tr>
<tr>
<td>105262, 81855, 601041, 550001, 722386</td>
</tr>
<tr>
<td>757568, 43248, 848242, 120642, 404848</td>
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<tr>
<td>659596, 93210, 866250, 143976, 779499</td>
</tr>
<tr>
<td>420212, 824642, 291308, 825896, 593765</td>
</tr>
<tr>
<td>648693, 777773, 372519, 819699, 778378</td>
</tr>
<tr>
<td>192758, 93855, 247375, 142267, 022395</td>
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<td>207731, 93074, 97802, 708024, 642659</td>
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<tr>
<td>266423, 85438, 113645, 631186, 973793</td>
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<tr>
<td>321468, 624548, 137778, 129798, 086237</td>
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<tr>
<td>997332, 287493, 26249, 276947, 725475</td>
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<tr>
<td>997259, 116823, 99822, 149398, 695293</td>
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<td>722805, 43120, 864870, 236920, 907867</td>
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<tr>
<td>576292, 93693, 925719, 251734, 360938</td>
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<tr>
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<td>669582, 70212, 770213, 402224, 453488</td>
</tr>
<tr>
<td>865180, 453144, 41427, 291374, 636240</td>
</tr>
</tbody>
</table>

Customer Demand = 10-30 unit.
Plant Capacity = 2000-4000 unit
Supplier Capacity = 4000-6000 unit

All these data are used in MATLAB by using multi-objective GA toolbox to proof the proposed model. Here all of these costs are assumed. Authors assumed 3 different scenarios to get more appropriate result in different GA. Among of them, scenario 3 kept in default. In this research we assume that...
In this research, the amount of product supplied by supplier to plant (X1), plant to DC (X2), DC to retailer (X3) are found, by these minimum cost value between one stage to another stage is found and by the value of earliness (the product which comes early to the due time) and tardiness (the amount of product which reached late) the minimum time is mentioned. Considering three resulted value, optimized cost value f1 is 2699.795 and optimize time value is 0.008031. These two types of minimization are objective function. The minimum value of (F1+F2) = 2699.803 is considered as a solution for all variables. Authors used Genetic Algorithm toolbox for this minimization.

After reviewed total result, Scenario 1 has given the best result. Graphs which are found for this default option is given below.

**Table 3. Optimized Value from GA**

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Amount of raw material supplied from supplier to plant, X1</th>
<th>Amount of products supplied from plant to Distribution Center, X2</th>
<th>Amount of products supplied from Distribution Center to Retailer, X3</th>
<th>Total number of backorders of products at distribution center in time t (tardiness) X4</th>
<th>Total number of products delivered to distribution center in time (earliness) X5</th>
<th>Optimized cost value f1</th>
<th>Optimized time value f2</th>
<th>Total f1+f2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>199,999.4</td>
<td>199,999.4</td>
<td>199,999.4</td>
<td>3.27</td>
<td>47.59</td>
<td>2699.795</td>
<td>0.008031</td>
<td>2699.803</td>
</tr>
<tr>
<td>2</td>
<td>199,971.4</td>
<td>199,980.5</td>
<td>199,990.4</td>
<td>2.425</td>
<td>12.62</td>
<td>2699.802</td>
<td>0.001293</td>
<td>2699.803</td>
</tr>
<tr>
<td>3</td>
<td>199,982</td>
<td>199,985.2</td>
<td>199,990.4</td>
<td>2.81</td>
<td>683.87</td>
<td>2899.82</td>
<td>0.08668</td>
<td>2899.906</td>
</tr>
</tbody>
</table>

**Fig 3. Different Pareto front & Histograms for scenario 1**

**Fig 4. Different Pareto front & Histograms for scenario 2**

**Fig 5. Different Pareto front & Histograms for scenario 3**

**Conclusion**

In this research, authors have developed a mathematical model for a supply chain network among four stages that minimizes total cost including transportation cost and minimize total holding time (Earliness & Tardiness) in distribution center. Genetic algorithm used to find the optimal time and cost of a supply chain network considering real world uncertainty. Considering a general supply chain network model consisting of suppliers,
manufacturing plants, distribution centers (DC), and retailers. Authors created a network and apply optimizing tool. Genetic algorithm searched extensively for the global optimal where the costs would be the lowest for the total supply chain. This research work has involved a multi echelon supply chain network. The cost functions used in the research requires different cost data. All the data used in this research are different for each member of the supply chain. In this model authors considered time as function and assumed one industry has many products, a number of distributors, retailers and suppliers. Supply chain network design problems are functions of different parameters namely lead times at each entity, fill rates, inventory management, retailers' and customers' demands. If all delivery and raw materials transportation can be done at much optimized way and only then the revenues can be enhanced very effectively. In this work authors have used three scenarios for getting better result. In recent years the interest in the supply chain coordination field has been growing.

So Authors have formulated an analytical mathematical model among four stages supply chain network to find the optimal cost with optimal shortest possible required time to increase effectiveness and revenue.

**Reference**


