Cost Optimization of a Manufacturing Industry using Genetic Algorithm – A Case Study

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Abstract— **A supply chain consists of all parties involved, directly or indirectly, in fulfilling a customer request. Optimization is the methodology for improving the quality and desirability of a product or product concept. It is the process of finding function extrema to solve problems and finding an alternative with the highest achievable performance or efficiency at a low cost under the given constraints, by maximizing desired factors and minimizing undesired ones. Management is a process of integrating and utilizing suppliers, manufacturers, warehouses and retailers, so that goods are produced and delivered at the right quantities and at the right time while minimizing costs as well as satisfying customer requirements. Each manufacturer or distributor has some subset of the supply chain that he must manage and run profitably and efficiently to survive and grow. Managing the entire supply chain becomes a key factor for successful business. Supply Chain Management can be best described as the natural extension of the downsizing and re-engineering performed by the organizations in the past. Downsizing and re-engineering transformed the enterprises into lean and mean competitive units, by cost cutting and process simplifications. The present work deals with managing the supply chain network of an industry and reducing the total operating cost of the industry by considering few constraints. In this work, the optimal solution of a supply chain network is obtained by using the non-traditional technique genetic algorithm (GA), along with software like MATLAB and 'C' program for the same modeling equation. This article deals with the optimization of the supply chain network of an organization by reducing the total operating cost considering various constraints.**

***Key words*—Supply chain management, optimization, GA, MATLAB, 'C' program, total operating cost**

I. INTRODUCTION

Today's best enterprises have increasingly looked upon supply chain management to provide fresh vistas for new sources of competitive advantage. The growth of supply chain management has been noted to take place in three stages such as traditional purchasing role, supply chain management through subcontracting and supply chain through innovation. Based on the definitions, supply chain management can be classified into four major areas namely the flow of materials and logistics, flow of information, integration and comprehensive flow. Supply chain management refers to the management of activities that procure raw materials, transform those materials into intermediate goods and final products and deliver the products through a distribution system to the end user. SCM manages the global network used to deliver products and services from raw materials to end customers through an engineered flow of information, physical distribution and cash. Supply Chain Management (SCM) is a set of approaches utilized to efficiently integrate suppliers, manufacturers, warehouses and stores so that merchandise is produced and distributed at right qualities, to the right locations at the right time in order to minimize system wide cost while satisfying service level requirements. SCM is a technique that looks at all the links in the chain from raw material suppliers through various levels of manufacturing to warehousing and distribution to final customer. SCM is a network of autonomous business entities, which are involved through upstream and downstream linkages in the different processes and activities that produce values in the form of physical products and services in the hands of the ultimate customers. SCM is used to describe the management of materials, suppliers, production facilities, distribution services and customers linked together through the feed forward flow of information and feedback flow of information. The supply chain is regarded as a sequence of material suppliers, production facilities, distribution services and customers. A supply chain consists of all stages involved, directly or indirectly in fulfilling a customer request. The supply chain not only includes manufacturers and suppliers, but also transporters, warehouses, retailers and customers. It is a network of facilities that performs the functions of procurement of material, its transformation to intermediate and finished products and its distribution to end customers. After analyzing the above definitions, it has been observed that the supply based selection, distribution and inventory based supply chain optimization and service level improvement through reverse logistics are considered important in the definition of SCM. Supply chain management has become an important management paradigm. In a typical supply chain, raw materials are procured and items are produced at one or more factories, shipped to warehouses for intermediate storage and then shipped to retailers or customers. Consequently, to reduce cost and improve service levels, effective supply chain strategies must take into account the interactions at the various levels in the supply chain. The

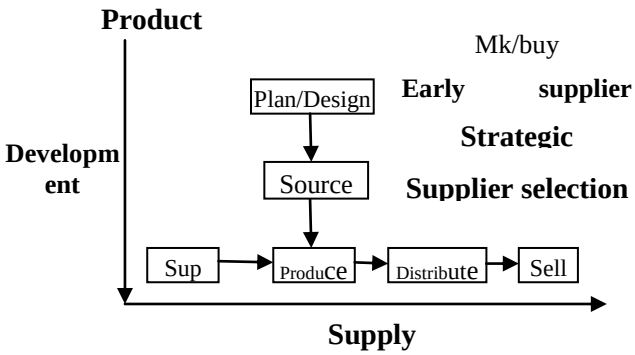
supply chain, which is also referred to as the logistics network, consists of suppliers, manufacturing centers, warehouses, distribution centers and retail outlets as well as raw materials, work-in-process inventory and finished products that flow between facilities. As supply chain members are often separate and independent economic entities, a key issue in supply chain management is to develop mechanisms that can align their objectives and co-ordinate their activities so as to optimize system performance. Enterprises today have realized the importance of supply chain management to achieve operational efficiency, cut cost and maintain quality.

Uncertainties in supply, demand, transportation, market conditions and many other factors can interrupt supply chain operations, causing significant adverse effects. The primary component of supply chain system consists of manufacturers, wholesalers and retailers. The manufacturing facility may be located at the same city or at different cities or in different states. Thus, there may be significant material flows between two consecutive manufacturing facilities. Supply chain management is the management of material and information flow both in and between facilities such as vendors, manufacturing, assembly parts and distribution centers (Sunil Chopra, 2010). The main processes in supply chain are production planning and control and distribution and logistics. The former describes the design of process and management of entire manufacturing process such as material handling, scheduling and inventory control. The latter determines how products are retrieved and transported from the factory or warehouse to customers. In the face of highly competitive markets and constant pressure to reduce lead times, enterprises today consider the supply chain management to be the key area where improvements can significantly impact the bottom line. More enterprises now consider the entire supply chain structure in decision making. They try to identify and manage all critical relationships both upstream and downstream in their supply chains.

Manufacturing and distribution companies are seeking to develop systems that analyze the corporate database to identify plans for re-designing their supply chain and operating them more efficiently. Essential components of these systems are optimization models, which can unravel the complex interactions and ripple effects that make supply chain management difficult and important. They are only analytical tools capable of fully evaluating large, numerical databases to identify optimal or demonstrably good plans. In addition to identifying cost minimizing or net revenue maximizing plans, optimization models measure the tradeoffs among these objectives and cost, service, quality and time. The application of an optimization model in a company requires the construction of an optimization modeling system. The key element in such a system is the supply chain decision database, which is derived from the company's corporate databases. It is constructed from aggregate descriptions of the company's products, customers and vendors. It contains the direct and indirect cost relationship, sub models of production transportation, ware housing and inventory management, cost and capacity information about parts and products offered by venders, order information and forecasts of demand for finished products. The supply chain of the industry (under study) comprises geographically dispersed facilities where raw materials, intermediate products or finished products are acquired, transformed, stored or sold and transportation links that connect facilities along which products flow. This work distinguishes between plans, which are manufacturing facilities where physical product transformations take place and distribution centers, where products are received, stored and dispatched but not physically transformed. The nodes in the network represent facilities, which are connected by links that represent direct transformation connections permitted by the company in managing its supply chain. The network has four levels of facilities. Products flow downstream from vendors to plants, plants to distribution centers and distribution centers to markets. In general, a supply chain network may have an arbitrary number of levels. The benefits of supply chain management include better risk allocation, greater visibility of sub contracting opportunities for a diverse range of organizations, effective supply chain management offers strong potential for innovation to be released through the supply chain, better defined requirements through early supply chain involvement in the shaping of the business need.

II. The Development Chain

The development chain is the set of activities and processes associated with new product introduction. It includes the product design phase, the associated capabilities and knowledge that need to be developed internally, sourcing decisions and production plans. Specifically, the development chain includes decisions such as product architecture, make or buy decisions, supplier selection, early supplier involvement and strategic partnerships. The development chain and the supply chain intersect at the production point. The characteristics of the decisions made in the development chain will have an impact on product design strategy and hence on the development chain (Sunil Chopra and Peter Meindl, 2010)



III. Modelling And Optimization

Optimization is an act, process or methodology of making a design, system or decision as fully perfect, functional or effective as possible. An optimization problem consists of maximizing or minimizing a real function by systematically

choosing input values from within an allowed set and computing the value of the function. More generally, optimization includes finding the best available values of some objective function from a defined domain, including a variety of different types of objective functions and different types of domains. Metaheuristic techniques are used for combinatorial optimization in which an optimal solution is sought over a discrete search-space. Optimization makes an exhaustive search for the optimal solution infeasible. Additionally, multi-dimensional combinatorial problems, including most design problems in engineering such as form-finding and behavior-finding, suffer from the curse of dimensionality, which also makes them infeasible for exhaustive search or analytical methods. Popular metaheuristics for combinatorial problems include simulated annealing genetic algorithms, ant colony optimization, scatter search and tabu search. Metaheuristic techniques are also used for problems over real-valued search-spaces, where the classic way of optimization is to derive the gradient of the function to be optimized and then employ gradient descent. Popular metaheuristic optimizers for real-valued search-spaces include particle swarm optimization, differential evolution and evolution strategies. Metaheuristics based on decomposition techniques have also been proposed for tackling hard combinatorial problems of large size.

IV. MODELLING EQUATION

The four stages considered for optimization are suppliers, plants, distribution centers and retailer zones. The problem is to capture the dynamics of a single product being manufactured out of 3 different components. There are 3 suppliers, 2 manufacturing plants, 3 distribution centers and 6 retailer zones in the industry under consideration. It deals with minimizing the total operating cost and maximizing the profit of the industry by using genetic algorithm and particle swarm optimization as the optimizing tool.

The work was carried out to achieve the objectives namely, to frame a generic model for validation using optimization techniques, to develop a mathematical model for the optimization of the supply chain network of a manufacturing industry under study, to minimize the total operating cost of the manufacturing industry by considering various constraints like suppliers, plants, distributors, retailers and customers using the optimization techniques like genetic algorithm and particle swarm optimization and to compare the two optimized results and suggest the industry under study with the optimum solutions for further implementation. There are three kinds of variables like supplier transmission variables, plant transmission variables and distribution center transmission variables used in this formulation (Table I).

TABLE I. VARIABLES USED

S.No.	Variables and Dependent factors	Meaning	Number of factors
1.	a =c × s × p	Amount of components transported from suppliers to plants	18
2.	b = p × d	Amount of components transported from plants to distribution centers	6
3.	c = d × r	Amount of components transported from distribution centers to retailer zones	18
Number of variables			42

where,c – Number of components = 3
s – Number of suppliers = 3
p – Number of plants = 2
d – Number of distribution centers = 3
r – Number of retailers = 6
Total number of variables = 42

The objective function equation and the constraints equation are given in the following equations

1. Total Operating Cost:

$$TOC = TC + SC + MC + DC$$

2. Transportation cost (TC):

$$TC = \sum_{c=1}^{c=3} \sum_{s=1}^{s=3} \sum_{p=1}^{p=2} \left(a_{c,s,p} \times TSP_{c,s,p} \right) + \sum_{p=1}^{p=2} \sum_{d=1}^{d=3} \left(b_{p,d} \times TPD \right)$$

3. Supplier cost (SC):

$$SC = \sum_{c=1}^{c=3} \sum_{s=1}^{s=3} \left(CS_{c,s} \times a_{c,s,p} \right)$$

4. Manufacturer cost (MC):

$$MC = \sum_{p=1}^{p=2} \left\{ \left(Mp \right) \times \left(\sum_{d=1}^{d=3} b_{p,d} \right) \right\} + \left\{ \sum_{p=1}^{p=2} \left(ICp \times \sum_{c=1}^{c=3} Ic,p \right) \right\}$$

5. Distributors cost (DC):

$$DC = \sum_{d=1}^{d=3} \sum_{r=1}^{r=6} \left(c_{d,r} \times TCD_{d,r} \right) + \sum_{d=1}^{d=3} \left(ICDd \times IDd \right)$$

6. Profit = $\left(\text{Demand} \times \text{Selling Price} \right) - TOC$

V. VARIOUS EXISTING COSTS IN THE INDUSTRY

The existing cost of all the constraint parameters that exists in the industry is given in the following tables. All these cost values were used for optimization using genetic algorithm and particle swarm optimization to reduce the total operating cost of the industry under study.

The details of the existing cost of the transportation of all the components manufactured in the industry from all the suppliers are given in the following tables.

TABLE II. EXISTING COST OF TRANSPORTATION - PLANT 1

	C1	C2	C3
S1	10	15	12
S2	8	7	10
S3	10	12	13

TABLE III. EXISTING COST OF TRANSPORTATION - PLANT 2

	C1	C2	C3
S1	14	18	19
S2	12	9	6
S3	15	16	14

TABLE IV. THE 'A' VARIABLE – EXISTING VALUES – PLANT 1

	C1	C2	C3
S1	85	70	90
S2	20	72	20
S3	22	10	18

TABLE V. EXISTING COST OF TRANSPORTATION FROM PLANT TO DISTRIBUTION CENTRES VARIABLES USED

	D1	D2	D3
P1	15	14	16
P2	13	14	16

TABLE VI. THE 'B' VARIABLE – EXISTING VALUES

	D1	D2	D3
P1	49	55	35
P2	135	60	55

TABLE VII. THE 'C' VARIABLE – EXISTING VALUES

	R1	R2	R3	R4	R5	R6
D1	56	102	10	5	12	4
D2	15	75	4	6	10	19
D3	25	12	10	18	8	11

The existing cost of inventory of distribution centre per unit (ICD): ICD1 = 70; ICD2 = 85; ICD3 = 90

The existing inventory at distribution centre (ID):ID1 = 150; ID2 = 180; ID3 = 165

The existing total operating cost and profit of the industry is given in Table 4.13. Based on these values the optimization is done to reduce the operating cost and increase the profit of the industry. The existing retailer zone demand: 100, 25, 50, 80, 90, 60

The existing selling price at retailer zone: 2000, 2500, 2750, 3000, 3200, 3500

TABLE VIII. EXISTING COST AND PROFIT

S.No.	Constraints	Existing Cost in Rs.
1.	Transportation cost	19,696
2.	Supplier cost	2,04,500
3.	Manufacturing Cost	7,11,575
4.	Distribution cost	43,683
5.	Total operating cost	9,79,454
6.	Profit	1,56,946

VI. GENETIC ALGORITHM CONTROL PARAMETERS

For selecting the control parameters, a detailed study has been made and among the various reproduction methods, the Roulette Wheel method is used. For this work, single point crossover is suitable and the optimization is done with different population sizes and finally at a population size of 20, the optimum value is reached. So, the population size is taken as 20. Also, the crossover probability is 0.08(80%) and mutation probability is 0.02(2%). Finally after 50 iterations the optimal cost value is reached for all the costs. The various control parameters are given below.

Population size = 20
Reproduction = Roulette wheel method
Crossover = Single point crossover
Crossover probability (Pc) = 0.55
Mutation = Single point mutation
Mutation probability (Pm) = 0.03
Termination criterion = Number of generations 500

VII. RESULTS AND DISCUSSIONS

By optimizing the supply chain network using genetic algorithm with matlab the constraints of the total operating cost i.e. supplier cost, manufacturing cost, distribution cost, transportation cost were reduced which results in reduction of the total operating cost (objective function) and increase in the profit of the industry. The optimized results were also obtained graphically and shown in figure 1 to figure 4.

FIG.1 SUPPLIER COST GRAPH

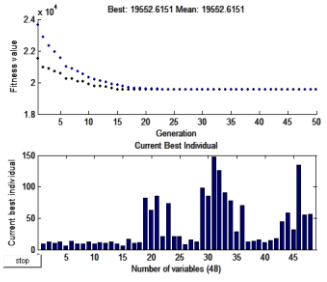


FIG.2 TRANSPORTATION COST GRAPH

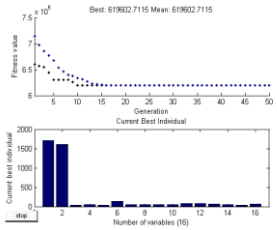


FIG.3 DISTRIBUTOR'S COST GRAPH

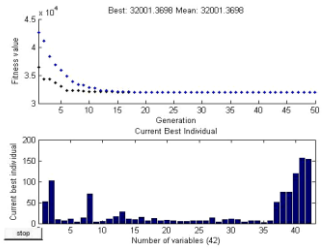
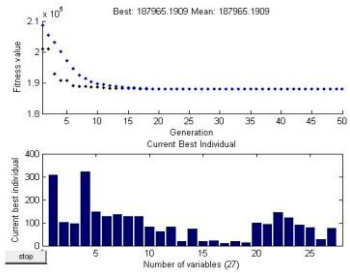


FIG.4 MANUFACTURING COST GRAPH



The optimized cost results were given in Table IX and the results were compared with GA using MATLAB and using 'C' language program. From the results it is clear that the profit is maximum in 'c' program than using MATLAB for the same set of modeling equations. Using this route the case industry can be benefited without compromising the quality of the product.

TABLE IX. OPTIMIZED COST RESULTS - MATLAB AND C PROGRAM

Name of the Cost	Existing cost details (Rupees)	Optimized cost result (Rupees)	
		In GA(matlab)	In GA('C' program)
Transportation cost	19,696	19,552	17,964
Supplier cost	2,04,500	1,87,965	1,80,865
Manufacturing Cost	7,11,575	6,19,603	6,00,523
Distribution cost	43,683	32,001	29,052
Total operating cost	9,79,454	8,59,121	8,50,564
Profit	**1,58,546**	**2,78,879**	**2,87,436**

VIII. CONCLUSIONS

This chapter deals with the overall results and discussions of which the objective function values (minimization of TOC) and their convergence obtained using GA(with matlab) and GA(with 'C' program).The major advantage of using these algorithms is that even though the number of possible sequences of operations to reach the optimum value is very high, an optimal solution is obtained within few minutes. The effectiveness of these algorithms is tested through computer simulation for various real life problems and is found to be very effective.

The results obtained shows that the GA (with 'c' program)approach is best when compared to GA (with MATLAB) because for the present problem the profit is higher with GA('C') and when the implementation is done in the case industry using the GA optimized results. Also, the quality is not compromised when implementing the GA results. GA(with 'C' Program) not only satisfies the customer's requirements and capacity restraints, but also offers a near minimum cost. The best individual of each generation is steadily converging to a near optimal solution with the process of generations. Finally, the supply chain network is analyzed and the component and product distribution with optimal total cost of the supply chain of the organization are optimized. The mathematical modeling can be modified according to the parameters involved in the manufacturing industries. The results are submitted to variation with respect to the real time environment. In order to monitor and control the real time environment, the post optimality analysis or sensitivity analysis can be conducted. In this work, a four stage echelon supply chain model is considered along with constraints like suppliers, manufacturing plants, distribution centers and retailer zones to reduce the total operating cost of the industry under study. This work is limited to only a few constraints and only two methodologies were

adopted. All the constraints are limited as per the discussion and the requirement of the industry under study. Supply chain management is a cross functional approach to manage the movements of raw materials into an organization and the movement of finished goods out of the organization towards the end customer.

IX. FUTURE SCOPE

With the encouraging results, this work could be extended to multi-product environment. The constraints which are limited to supplier cost, manufacturing cost, transportation cost and distributor's cost can be increased to labour cost, service cost, etc. in future. In the optimization to increase the profit by decreasing the total operating cost, instead of genetic algorithm, particle swarm optimization and hybrid of both the optimal resource allocation could be tried with other non-traditional algorithms. The research reported in this study makes an attempt to model and analyze the supply chain models for various conditions. It was not feasible to include all possible aspects of research due to limited scope of study. Hence, it is suggested that future research work could examine the following important issues.

i) In the future work, different constraints may be considered with the optimization and that also can be included in the optimization sequence.
ii) The standard optimization techniques used in this work can be extended to other type of objective functions like time minimization, labour minimization, etc.
iii) The details of computational time of each technique to find optimal solutions for the objective can be assessed.
iv) Each supply chain design considered for this research can be evaluated with various solution methodologies.

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