



SUPPLY CHAIN LOGISTICS NETWORK OPTIMIZATION FOR MINIMISING COST, CONSIDERING TRANSPORTATIONAL DAMAGE

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Abstract- In today's vibrant and competitive environment, companies are continuously trying to provide products and services to end user at its best quality and satisfaction, and also with better profit than the competitors do. Companies realized that plenty of reasons prevail for a customer to choose other competitors in the business. Managers have learned that choosing partners and making alterations in supply chain combinations have to be performed in the supply chain level for being profitable and efficient in the game and for making the customers delighted. Although the resulting enterprise networks are more competitive, the tasks for planning, management and optimization are much more difficult and complex and to be decided with least time. In this paper, we present a new method developed using genetic algorithm for designing Multi supplier and single warehouse chain where average cost of a product over order filling is considered as the objective for optimization. Product damage rate and product damage cost are newly considered along with cost components for assuring no defective product is delivered to the end user. To show the result a numerical example is taken from the literature.

Keywords – SCN Optimization, Genetic Algorithm and Supply chain cost optimization.

I. INTRODUCTION

The business environment in the current world is becoming increasingly uncertain, unpredictable, complex, and as a result, highly competitive. Increased competition makes companies to face the multi challenges of reducing costs at the same time being more responsive to the customers. The studies over these issues throughout the world realized that, though there may be diverse and situation specific solutions to the problems posed by these challenges, flexibility has to be the essential feature of the procedures used to handle these variations. Due to the increase in competition and

complexity, Supply Chain Management (SCM) has emerged as a highly important issue for private as well as public enterprises. A supply chain links - design, sourcing, manufacturing, and logistics activities along the organizations. The chain links suppliers and customers, beginning with the production of raw material by a supplier followed by the consumption of a final product by the consumer. In a supply chain, the flow of goods between a supplier and customer passes through several stages, and each stage may consist of many facilities [10].

In recent years, the supply chain network (SCN) design problem has been gaining importance and are under the limelight of serious and critical studies due to increasing competitiveness introduced by the market globalization [17,24,25]. The network design problem is one of the most comprehensive strategic decision problems that need to be optimized for long-term efficient operation of whole supply chain. It determines the number, location, capacity and type of plants, warehouses, and distribution centers to be used. It also establishes distribution channels, and the amount of materials and items to consume, produce, and ship from suppliers to customers. Most of supply chain network design problems can be reduced to capacitated facility location problem (CFLP) which is known to be NP-complete ; therefore, most of supply chain network design problems are NP-hard[26,27]. In the present article, a new method, has been proposed and shows the application of it in the SCN optimization problem. The SCN problem is a very complex problem and the decision making is also very difficult for the managers. In this study, a single objective, minimization of the total average cost per fill demand is considered. In this paper cost components consists of a new introduction called product damage

cost. This cost helps in finding better and safe transportation and also the amount of damage product derived by the algorithm ensures that no single damaged product will reach the end user. This simulation is done using simple genetic algorithm. To show the efficiency of the proposed algorithm, a benchmark problem from the literature has been taken and it is also tested on the few moderate size of the problem. The remainder of this paper is described as following: Section 2 presents the literature review of supply chain network optimization and employment of genetic algorithm in it. Section 3 delineates the complexity of the problems along with the mathematical model. The optimization procedure has been described in Section 4. Section 5 is having the details of case study for validation and section 6 describes the Results obtained and its analysis followed by, section 7 having conclusion and future proposals.

II. LITERATURE REVIEW

A. Single Objective Optimizations

In traditional SCM, the focus of the integration of SCN is usually on single objective such as minimum cost or maximum profit.

In literature, there are different studies dealing with the design problem of supply networks and these studies have been surveyed by Erenguc et al. [1], Pontrandolfo and Okogbaa [2]. In traditional SCM, almost all researchers concentrated on optimizing single objectives either minimum cost or maximum profit [3, 5, & 6]. These approaches are involved in tackling the various components of costs or the tradeoffs between those components. Amiri [3] has presented a Lagrangian relaxation approach to minimize the total cost of two stage supply chain. Costa et al. [4] have worked on three stage supply chain network optimization problem. The objective of the research is to minimize the total cost of supply chain. Jayaraman and Pirkul [7], Jayaraman and Ross [8], Yan, Yu, and Cheng [9], Gen and Syarif [11] and Truong and Azadivar [12] had considered total cost of supply chain as an objective function in their studies.

B. Multi Objective Optimizations

However, there are no design tasks that are single objective problems. Recently, multi objective optimization of SCNs has been considered by different researchers in literature. The design/planning/scheduling projects are usually involving trade-offs among different incompatible goals. Sabri and Beamon [10] developed an integrated multi-objective supply chain model for strategic and operational supply chain planning under uncertainties of product, delivery and demand. While cost, fill rates, and flexibility were considered as objectives, ϵ -constraint method had been used as a solution methodology. Chen and Lee [14] developed a multi-product, multi-stage, and multi-period scheduling model for a multi-stage SCN with uncertain demands

and product prices. As objectives, fair profit distribution among all participants, safe inventory levels and maximum customer service levels, and robustness of decision to uncertain demands had been considered, and a two-phased fuzzy decision-making method was proposed to solve the problem. Erol and Ferrell [15] proposed a model that assigning suppliers to warehouses and warehouses to customers. They used a multi-objective optimization modeling framework for minimizing cost and maximizing customer satisfaction. Guillen et al. [16] Formulated the SCN design problem as a multi-objective stochastic mixed integer linear programming model, which was solved by ϵ -constraint method, and branch and bound techniques. Objectives were SC profit over the time horizon and customer satisfaction level. Shen et al. [18] Proposed an integrated stochastic supply chain design model that takes into consideration the location, inventory and routing costs. They considered a three-tiered supply chain system consisting of one or more suppliers, distribution centers and customers with uncertain demand that follows a certain probability distribution. Inventory holding costs and transportation costs were assumed to exhibit economies of scale. Cardona-Valdes et al. [19] have presented a study of multi-echelon supply chain network designing problem and they have considered the economical aspect with customer service level Franca et al. [22] proposed a multi-objective stochastic programming model that seeks to find the supply chain configuration that maximizes the profit and minimizes defective materials from suppliers. Huang et al. [23] studied three types of uncertainties in a closed-loop supply chain of the Chinese steel industry: uncertainty of time delay in remanufacturing and return, of costs are considered.

C. Optimizations Using Genetic Algorithms(GA)

During the last decade, there has been a growing interest using genetic algorithms (GA) to solve a variety of single and multi-objective problems in production and operations management that are combinatorial and NP hard. Chan and Chung [13] proposed a multi-objective genetic optimization procedure for the order distribution problem in a demand driven SCN. They considered minimization of total cost of the system, total delivery days and the equity of the capacity utilization ratio for manufacturers as objectives. Fulya Altiparmak et al. [17] In the study, they proposed a new approach based on GA for multi-objective optimization of SCNs which is one of the NP hard problems. Three objectives were considered: (1) minimization of total cost comprised of fixed costs of plants and distribution centers (DCs), inbound and outbound distribution costs, (2) maximization of customer services that can be rendered to customers in terms of acceptable delivery time (coverage), and (3) maximization of capacity utilization balance for DCs (i.e. equity on utilization ratios). The proposed GA was designed to generate Pareto-optimal

solutions considering two different weight approaches. To investigate the effectiveness of the proposed GA, an experimental study using actual data from a company, which is a producer of plastic products in Turkey, was carried out into two stages. While the effects of weight approaches on the performance of proposed GA were investigated in the first stage, the proposed GA and multi-objective simulated annealing (MO_SA) were compared according to quality of Pareto-optimal solutions in the second stage. Chan et.al. [13] Developed a hybrid approach based on Genetic Algorithm (GA) and Analytic Hierarchical Process (AHP) for production and distribution problems in multi factory supply chain models. Guillen et al. [16] have worked on multi-objective supply chain network designing problem. They employed a branch and bound algorithm and the objectives are profit of supply chain and customer service. Whereas, Altiparmak et al. [17] have considered total cost, customer service and capacity utilization to design a supply chain network. Prakash and Deshmukh [20] have also presented an approach to allocate the warehouse to the customers. They have also taken as a multi-criteria problem by considering transportation time and transportation cost. A hierarchical combination of mixed-integer programming and a genetic algorithm has been proposed in Truong and Azadivar [12] to determine simultaneously the values of quantitative as well as policy variables. Altiparmak et al. [17] have also applied the GA to solve such problem with three objectives: minimization of total cost, maximization of customer service, and maximization of capacity utilization. Farhani and Elahipana [21] have also applied GA for distribution network optimization. They considered two objectives: minimization of costs and minimization of the backorders. Gen et al., [11] have proposed a GA based approach to cope with network multiple objective problems. Lee et al. [16] have also applied the GA for the optimization of reverse logistics network problem. From the aforementioned literature review, it has been seen that the researchers are concerned about the customer satisfaction i.e. to fulfill the demand within time and decrease the cost.

III. MATHEMATICAL MODEL

A. Problem Description

In supply chain network designing problem, logistic cost form the major part of a supply chain's costs. Inventory control and distribution planning, as fundamental logistical processes, affect the total costs of the supply chain to a great extent, but, on the other hand, have a great effect on the customer's demand fill rate. Every suppliers should deliver the right amount of goods, at the right time, and to the right place. In the present work, we are considering an ongoing business with a supplier and we are trying to redesign the network with another alternative source such that best of the objectives can be attained. Here the business scenario under consideration

is multiple suppliers (local and abroad) with same product but with different unit product prices and cost of services. The product is reached to the retailers (considered as customer) who are having a uniform demand for the product. The customer gets the product from a single warehouse of a sole distributor who engages with the supplier for the product upon the demand from the customer. Each supplier is considered having different modes of transport for carrying the product to warehouse in accordance with their location. The logistics cost vary according to the mode selected for transport. The inventory is controlled by the warehouse.

In this study, to evaluate the total cost, seven different costs have been taken into consideration. These costs are the engagement cost, purchasing cost, transportation cost, inventory holding cost, ordering cost, product damage cost and penalty cost due to unfilled demand of the orders. Along with cost total demand fill rate is also evaluated considering that no damaged product reaches the customer. In this study, since the damage rate is considered, no product out of quality will reach the customer.

B. Assumptions for formulation

- Demand satisfied from single warehouse (total demand in a period is only considered).
- Customer is impatient; they are not ready to get the backlogs satisfied, so backlogs are considered as lost demand.
- Non identical suppliers with single or multiple mode of transport with variable parameters.
- Periodic review of inventory, order placed if stock is below ROP for a quantity Q .
- The ROP and Q are initially decided.
- Supplier as well as individual links will not take order below 10 % of the order quantity for taking advantage of the economies of scale.
- No single damaged product will reach the customer.

C. Mathematical Formulation

1) Notations

i - Supplier's index (1, 2, 3, ..., n)

j - Transportation link's index (1, 2, 3, ..., m)

k - Number of days

O_i - Number of orders placed to i th Supplier

L_{ij} - Percentage of Damage through j th link of i th supplier

2) Parameters

C_{Eng} - Total Engagement Cost

C_{Inv} - Total Inventory Cost

C_{Pur} - Total Purchasing Cost

C_{Ord} - Total Ordering Cost

C_{Trans} - Total Transportation Cost

C_{Dmg} - Total Damage Cost

d - Mean of Daily demand quantity

D_{Total} - Total demand of items

D_{lost} - Total unsatisfied Demand

C_{PLC} - Total Penalty Cost on lost demand

p - Penalty cost per item

E_{c_i} - Engagement cost for i_{th} supplier

N_{pur} - Number of items purchased from i_{th} supplier

UC_i - Unit purchasing cost (determined by i_{th} supplier)

N_k - Inventory of items per day

h - Holding cost per item per day

N_{oi} - Number of orders placed to i_{th} supplier

oc_i - Ordering cost per order for i_{th} supplier

Tr_{ij} - Number of transshipped products from j_{th} mode of transportation link of i_{th} supplier

Tc_{ij} - Transportation cost per item from j_{th} transportation link of i_{th} supplier

$Tdmg_{ij}$ - Number of product that may get damaged when transshipped through j_{th} transportation link of i_{th} supplier

OR_{sup_i} - Order placed to i_{th} supplier

$LB_{sup_{ij}}$ - lower bound limit of order placed to i_{th} supplier (minimum number of items ordered represented as % of Q)

3) Objective

The objective is to minimize the total average cost per fill demand keeping satisfaction at constrain. The mathematical formulation for the objective function is given below.

$$F1 = C_{Eng} + C_{Inv} + C_{Pur} + C_{Ord} + C_{Trans} + C_{DMG} + C_{PLC}$$

$$D_{Total} - D_{Lost} \text{ (Eq.1)}$$

To calculate the first objective, the individual cost can be calculated as follows:

$$C_{Eng} = \sum_i^n eci * zi, \square i \text{ (Eq.2)}$$

$$C_{pur} = \sum_i^n Nprchi * UCi, \square i \text{ (Eq.3)}$$

$$C_{DMG} = \sum_i^n \sum_j lij * TRij * Uci * Xij \text{ (Eq.4)}$$

$$C_{ord} = \sum_i^n \sum_o noi * oc * yoi, \square io \text{ (Eq.5)}$$

$$C_{Trans} = \sum_i^n \sum_j TRij * tcij * Xij, \square ij \text{ (Eq.6)}$$

$$C_{inv} = \sum_k Nk * h \text{ (Eq.7)}$$

$$C_{PLC} = D_{Lost} * p \text{ (Eq.8)}$$

4) Constraints

The calculation of the above objectives are subjected to the following constrains

$$\sum_i OR_{sup_i} \geq D_{total} \text{ (Eq.9)}$$

$$TR_{sup_{ij}} \geq LB_{sup_{ij}}, \square ij \text{ (Eq.10)}$$

$$LB_{sup_{ij}} \geq 0.10 \text{ (Eq.11)}$$

$$OR_{sup_i} = \sum_j TR_{ij} * X_{ij}, \square ij \text{ (Eq.12)}$$

$$\sum_i^n \sum_j TR_{ij} * X_{ij} \geq D_{total} \text{ (Eq.13)}$$

$$X_{ij} = \begin{cases} 1 & \text{if } j_{th} \text{ transportation link of } i_{th} \\ & \text{supplier is activated} \\ 0 & \text{otherwise} \end{cases} \text{ (Eq.14)}$$

$$y_{oi} = \begin{cases} 1 & \text{if } o_{th} \text{ order is placed to } i_{th} \\ & \text{supplier} \\ 0 & \text{otherwise} \end{cases} \text{ (Eq.15)}$$

$$z_i = \begin{cases} 1 & \text{if } i_{th} \text{ supplier is engaged} \\ 0 & \text{otherwise} \end{cases} \text{ (Eq.16)}$$

$$k, o, p, N_k, Lbsup_i \geq 0 \text{ (Eq.17)}$$

$$(D_{total} - D_{lost}) / D_{Total} \geq 0.8 D_{Total} \text{ (Eq.18)}$$

The objective function (Eq. (1)) is to minimize the average of all the incurred cost. The sixth cost component is the damage cost which is the newly introduced cost which will be incurred for the entire product which reaches the warehouse in damaged condition. Eqs. (2) to (8) show the formulation of different costs like engagement cost, purchasing cost, ordering cost, transportation cost, and inventory cost. The novelty of this mathematical model is to penalize on each lost demand. The penalty cost has been stated in mathematical form in Eq. (8). The constraints are given in Eqs (9) to (18). Eq. (9) shows that the order placed to the supplier should not be less than demand of the customers whereas Eq. (10) illustrates that the order placed to an individual supplier should not be less than a minimum number of items or lower bound of the order. The total number of transshipped items from all the transportation links of a supplier should be equal to the order placed to that supplier and it should be more than total demand from the customers. These constraints have been modeled mathematically in Eqs. (10) and (11). Finally, constraints in Eqs. (14)–(16) enforce the binary nature of the configuration decisions while Eq. (17)

imposes the non-negativity restriction of the decision variables corresponding to transshipment, orders etc. Eq.(18) conveys that the number of satisfied demand that is demand fill rate should be greater than 90% .

IV. PROCEDURE FOR OPTIMIZATION

A. Chromosome Representation

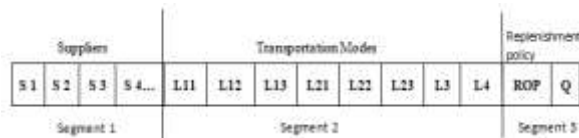


Fig.1 Chromosome structure

1)Segment 1

This segment represents the different suppliers those are involved in the business. The decision represented by this segment is that which all suppliers are selected for a particular best combination of the supply chain network. Here the suppliers selected will provide the product of same specification but with different cost parameters.

2)Segment 2

This segment represents the different modes of transportations available for each supplier. The number of modes may depend on the locational characteristics of the suppliers. Upon selection of supplier the respective modes of those suppliers will be included in the segment.

3)Segment3

Replenishment policy is represented in this segment where a reorder point and an EOQ will be represented which will control the inventory flow for a given demand.

B. Supplier selection

First task in the optimization is the selection of genuine suppliers among the available suppliers global as well as local. Among these genuine suppliers considering all different parameters served by a supplier must be collectively analyzed and best combination among them should be decided for the achievement of the objectives. Each supplier will be given two binary values '0' and '1' where '1' indicates the supplier is selected and '0' if not. There will be a potential supplier considered who is providing the supplier some advantages and would be considered in each combination. Other suppliers will be selected in random combinations by varying the quantity of products ordered from them.

C. Transportation mode selection

In order to handle the speed of arrival of the product at central warehouse different modes of logistics are considered. Number of different modes available for each supplier depends on the location of the supplier. If a supplier is selected during the above step the different

modes of logistics for the respective supplier will be made live.

D. Quantity Allocation

A value between 0-100 will be randomly selected into the different live genes of the selected supplier such that sum of the values should be exactly equal to 100. Considering the economies of a scale each value in different genes should be greater than 10. These values selected decides the percentage of the EOQ placed that should be delivered by each supplier through respective logistic mode. If any logistic mode is having a value less than 10, that percentage will be distributed to other potential mode of the respective supplier.

E. Replenishment policy

Replenishment policy differs from business to business considering various factors like market demand, lead times, inventory holding cost etc. In this method, R and Q method is used also weekly review system is introduced. A reorder point (ROP) will be decided in relation to the demand and lead times of the different suppliers who are engaged in the business. During the weekly review if the stock is found below ROP an order for quantity Q will be placed.

F. Inventory flow

Inventory flow will be started with a base stock. Each day a quantity equal to product demand will be reduced from the stock and simultaneously the holding cost will also be recorded. Number of product placed to each supplier will reach the warehouse accordingly with the lead times and will be added to the stock of that particular day. The damaged product will be reduced from the stock that is to be delivered to the customer such that no faulty product reaches the customer which will reduce level of customer satisfaction.

G. Cost components and calculation

In this study, to evaluate the total cost, seven different costs have been taken into consideration. These costs are the engagement cost, purchasing cost, transportation cost, inventory holding cost, ordering cost, damage cost and penalty cost due to unfilled demand of the orders. The cost provided from all the suppliers and the duties according to their physical situations. Purchase cost or the unit product cost will vary from supplier to supplier according to their facility and location. Engagement cost is introduced when a new supplier is selected, representing the costs for contract negotiation and so forth. Transportation cost is calculated for each product and may vary according to the mode selected. A fixed ordering cost will be placed for all orders placed irrespective of the supplier. Damage cost is that cost incurred by the distributor for keeping the faulty product with him and not delivering it to the customer. Penalty cost is the cost that will be added to the total supply chain cost in case of failure to meet customer demand.

H. Demand fill- rate calculation

Demand fill rate indicates how much percentage of the total demand from market is satisfied. This gives a measure of customer satisfaction. It is calculated by knowing the total demand came for the entire period and the number of backorders created for the period. The demand fill-rate is kept in constrain.

I .Simple Genetic algorithm operations (SGA)

Steps involved in SGA are:

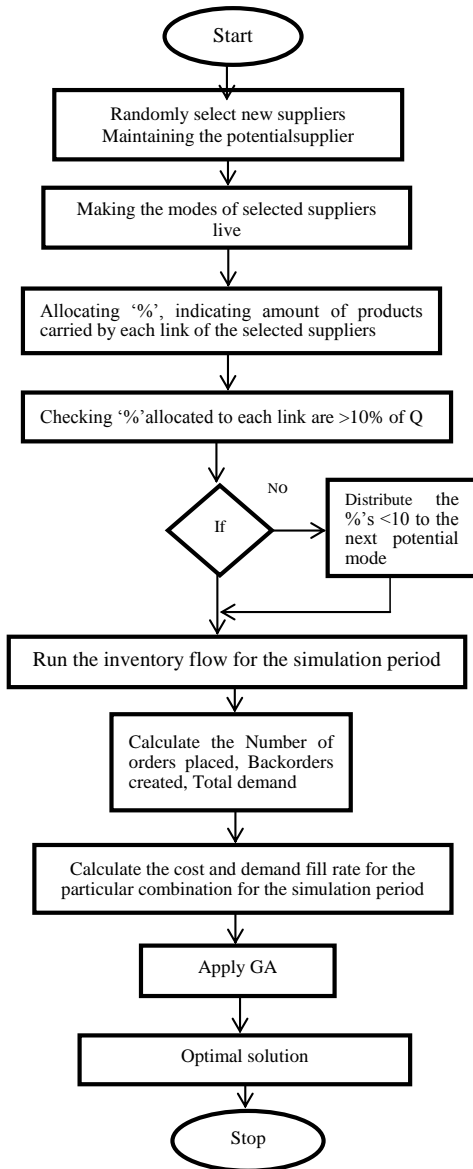


Fig.2 Optimization flowchart

1) Population Initialization

A population is a collection of individuals. A population consists of a number of individuals being tested, the phenotype parameters defining the individuals and some

information about search space. The two important aspects of population used in Genetic Algorithms are:

- The initial population generation.
- The population size.

For each and every problem, the population size will depend on the complexity of the problem. It is often a random initialization of population is carried. In this case a binary coded chromosome (segment 1) is initialized to a random zero or one. For each random selection the integer values at segment two also varies randomly from 0-100. And the values at the 3rd segment are constant which is calculated initially. Here the initialization of population is carried out without any known good solutions. The first population have a gene pool size is varied in order to be able to explore the whole search space.

All the different possible alleles of each gene are present in the population. To achieve this, the initial population is, in most of the cases, chosen randomly. The size of the population was raised for fewcases. The larger the population is, the easier it is to explore the search space. But it has established that the time required by a GA to converge is $O(n \log n)$ function evaluations where n is the population size. We say that the population has converged when all the individuals are very much alike and further improvement may only be possibly by mutation. Practically, a population size of around 100 individuals is found to be quite frequent, but anyway this size can be changed according to the time and the memory disposed on the machine compared to the quality of the result to be reach

TABLE 1: INITIAL POPULATION

		Segment 1			
Random generated Population Size(n)	Chromosome 1	1	1	1	0
	Chromosome 2	1	0	1	0

	Chromosome n	1	1	11	.

2) Selection

Selection is the process of choosing two parents from the population for crossing. After deciding on an encoding, the next step is to decide how to perform selection i.e., how to choose individuals in the population that will create offspring for the next generation and how many offspring each will create. The purpose of selection is to emphasize fitter individuals in the population in hopes that their off

springs have higher fitness. Chromosomes are selected from the initial population to be parents for reproduction. The problem is how to select these chromosomes. According to Darwin's theory of evolution the best ones survive to create new offspring. Selection is a method that randomly picks chromosomes out of the population according to their evaluation function. The higher the fitness function, the more chance an individual has to be selected. The selection pressure is defined as the degree to which the better individuals are favored. The higher the selection pressured, the more the better individuals are favored. This selection pressure drives the GA to improve the population fitness over the successive generations. Selection has to be balanced with variation form crossover and mutation. Too strong selection means sub optimal highly fit individuals will take over the population, reducing the diversity needed for change and progress; too weak selection will result in too slow evolution. There are different selection methods, for this work roulette wheel selection is used.

Roulette selection is one of the traditional GA selection techniques. The commonly used reproduction operator is the proportionate reproductive operator where a string is selected from the mating pool with a probability proportional to the fitness upon a fitness function and the fitness function used in this study is [29]:

$$\text{Fitness} = \left(\frac{1}{1+f(x_i)} \right) \quad (\text{Eq 19})$$

Where f(x) is the individual function F1 calculated along eachchromosome.

The principle of roulette selection is a linear search through a roulette wheel with the slots in the wheel weighted in proportion to the individual's fitness values. A target value is set, which is a random proportion of the sum of the fitness's in the population. The population is stepped through until the target value is reached. This is only a moderately strong selection technique, since fit individuals are not guaranteed to be selected for, but somewhat have a greater chance.

A fit individual will contribute more to the target value, but if it does not exceed it, the next chromosome in line has a chance, and it may be weak. It is essential that the population not be sorted by fitness, since this would dramatically bias the selection. The above described Roulette process can also be explained as follows: The expected value of an individual is that fitness divided by the actual fitness of the population. Each individual is assigned a slice of the roulette wheel, the size of the slice being proportional to the individual's fitness. The

wheel is spun N times, where N is the number of individuals in the population. On each spin, the individual under the wheel's marker is selected to be in the pool of parents for the next generation.

This method is implemented as follows:

- a). Sum the total expected value of the individuals in the population. Let it be T.
- b). Repeat N times:
 - i. Choose a random integer 'r' between 0 and T.
 - ii. Loop through the individuals in the population, summing the expected values, until the sum is greater than or equal to 'r'. The individual whose expected value puts the sum over this limit is the one selected.

Roulette wheel selection is easier to implement but is noisy. The rate of evolution depends on the variance of fitness's in the population.

3)Crossover

The traditional genetic algorithm uses single point crossover, where the two mating chromosomes are cut once at corresponding points and the sections after the cuts exchanged. Here, a cross-site or crossover point is selected randomly along the length of the mated strings and bits next to the cross-sites are exchanged. If appropriate site is chosen, better children can be obtained by combining good parents else it severely hampers string quality.

Single point cross over is done at the second segment in a stage when the allele values are binary in nature. The cross over site selection is random based on the length of the string. As the cross over takes place the program checks whether the supplier is made live or not, otherwise those chromosomes will be discarded as a filtration process for reducing the simulation complexity.

TABLE 2: CROSSOVER REPRESENTATION

		Segment 2			
Parent Chromosome	Chromosome 1	1 1 1	1 1 1	1	0
	Chromosome 2	1 0 1	0 1 1	0	1
Child Chromosome	Offspring 1	1 1 1	1 1 1	0	1
	Offspring 2	1 0 1	0 1 1	1	0

4)Mutation

After crossover, the strings are subjected to mutation. Mutation prevents the algorithm to be trapped in a local minimum. Mutation plays the role of recovering the lost genetic materials as well as for randomly disturbing

genetic information. It is an insurance policy against the irreversible loss of genetic material. Mutation has traditionally considered as a simple search operator. If crossover is supposed to exploit the current solution to find better ones, mutation is supposed to help for the exploration of the whole search space. Mutation is viewed as a background operator to maintain genetic diversity in the population. It introduces new genetic structures in the population by randomly modifying some of its building blocks. Mutation helps escape from local minima's trap and maintains diversity in the population. It also keeps the gene pool well stocked, and thus ensuring ergodicity. A search space is said to be ergodic if there is a non-zero probability of generating any solution from any population state. There are many different forms of mutation for the different kinds of representation. For binary representation, a simple mutation can consist in inverting the value of each gene with a small probability. The probability is taken about $1/L$, where L is the length of the chromosome. Mutation of a bit involves flipping a bit, changing 0 to 1 and vice-versa for the same segment of string where crossover has been conducted.

5) Selection of the best solution

After the mutation since the function is minimization, the minimum of the set is stored. At each subsequent generation this best will be replaced if another value less than the pre stored value comes .since the demand fill rate is kept as constrain the selection of value checks the region where the demand fill rate is and if it is a permissible value the lowest average cost gets in, else will be discarded.

When the termination criteria is reached the optimal best solution will be displayed which will give an idea how the SCM network should be designed for a specific inventory policy.

TABLE 3: MUTATION OPERATION REPRESENTATION

		Segment 2						
Before Mutation	Offspring 1	1	1	1	1	1	0	1
	Offspring 2	1	0	1	0	1	1	0
After Mutation	Mutated Offspring 1	1	1	1	1	0	1	0
	Mutated Offspring 2	0	0	1	0	1	1	0

V. VALIDATION

A. Industrial Profile in Case Study

The proposed case study is part of the supply chain for "Classic" boots of an Italian textile company [11]. The company outsourced production to outside contractors and it focuses only on marketing issues. For the actual situation (Fig. 3), the product is made by a unique

supplier in Vietnam (Supplier 1or S1). Boots are then collected in containers and transported by boat from Hochimin harbor to Genova harbor. From Genoa, boots are transported by trucks to the central warehouse near Ferrara, where they are stored. The product is then distributed to the retailers of the Italian market. The overall objective is to redesign the supply chain, mainly by: Evaluating different configurations by selecting new suppliers plus transportation links, basing the choice upon criteria as global cost and customer service level, Evaluating the sensitivity of the solutions to the market demand variation, Evaluating the impact of data uncertainty on the reliability of the supply chain and Evaluating the effects of changes in the central warehouse inventory policy.

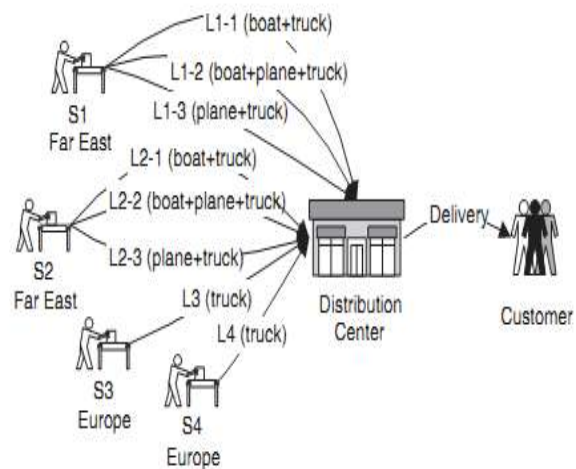


Fig.3: SCM for the case study

The suppliers to consider are: Actual supplier (Supplier 1-S1), a new supplier in Far East (Supplier 2-S2), a new supplier in East Europe (Supplier 3-S3) and a new supplier in Italy (Supplier 4-S4). More specifically, one potential supplier, denoted by Supplier 1-S1, who is already in the business and a portion of the total quantity, should be mandatorily given to S1. In order to reduce the order-to-delivery lead-time, the company proposes additional transportation. In this study, to evaluate the total cost, seven different costs have been taken into consideration. These costs are the engagement cost, purchasing cost, transportation cost, inventory holding cost, ordering cost, Damage cost and penalty cost due to unfilled demand of the orders. The cost provided from all the suppliers and duties according to their physical situations are given in Table 4. From the table, it is clearly shown that supplier 2 provides the boots at the lowest cost. Likewise features of each supplier vary among each. The transportation features are provided in Table 5. The main objective to solve such supply chain network optimization problem is to evaluate the selection of different suppliers or set of the suppliers and transportation links simultaneously, whereas the performance criteria are the total cost and

demand fill rate. Simultaneously, this study also satisfies some other goals like the impact of the performance by demand variation and the impact of inventory policy changing. From the figure, supplier 1 is the actual or existing supplier which is situated in Vietnam and one of the new or proposed suppliers (supplier 2) is in the Far East whereas supplier 3 is in the East Europe and the last one (supplier 4) is the local supplier i.e. that is situated in Italy itself. Supplier has a daily demand of 300 with a variance of 50

B. Supplier parameters

Different suppliers poses different feature depending upon the location, manufacturing methods, manpower availability, resource availability, taxes and duties ,different government policies etc. by selecting different suppliers we can extract the best from each suppliers, and also get the products with different prices according to the demanded situations. There will be some potential supplier present in supply chains who can provide products with competitive prices. Main components considered while observing suppliers are engagement cost, purchase cost ordering cost and lead-times. Details are given in Table: 4

TABLE 4: SUPPLIER PARAMETER DETAILS

Supplier ID	Engagement cost	Price per pair	Duties Suppl y lead-time (day)	Lead Time	Min. order size (pair)
1	0	12£	10%	15	0.10*Q
2	100000£	10£	20%	20	0.10*Q
3	80000£	14£	0	10	0.10*Q
4	100000£	16£	0	8	0.10*Q

C. Transportation parameters

As mentioned in the topic selection of supplier, transportation attributes are also depended on various external as well as internal factors. Major factors that have got remarkable effect on transportation parameter are locational terrain, availability of transportation modes, technological development of the area of suppliers, Location of warehouse, nature of demand. Etc. main components considered here for fixing transportation cost are the unit logistic cost, damage rate through each mode and the lead-times caused by different modes. For this study modes of transport available for S1 are L11, L12 and L13 whereas L21, L22, L23 represents modes for S2 and L3, L4 for S3 and S4 respectively. Details are given in table: 5

D. Inventory Replenishment policy

Product replenishment in this a case follows R and Q approach where a demand is there on that basis a

Reorder level is calculated .For this study R is kept as 6351 and Q as 1652. Upon reaching the ROP level an order quantity is placed. At each order placed an order cost will be incurred. Based on the daily demand the warehouse inventory varies and the number of received product demand and number of lost demands due to damage as well as lack of responsiveness is analyzed. Components for optimization calculated are the penalty cost and the average inventory holding cost for Product details are given in table: 6

TABLE 5: TRANSPORTATION PARAMETER DETAILS

ID	Lead Time(Days)	Unit Logistics cost Per pair	Damage Rate
L11	20	0.5£	0.02
L12	8	2£	0.05
L13	5	4£	0.01
L21	25	0.5£	0.02
L22	10	2£	0.05
L23	5	4£	0.01
L3	4	1£	0.01
L4	2	0.2£	0.01

TABLE 6: INVENTORY COST PARAMETERS

Ordering cost/unit	100£
Penalty cost/unit	2£
Inventory cost/unit	2.5£

VI. RESULT ANALYSIS

A. Results Obtained

The final result analysis conveys many advantages of the algorithm method for optimization

We ran the optimizer for different generations and population sizes. The possibilities of crossover and mutation are set as 0.9 and 0.3, respectively. Roulette wheel selection and random one-point crossover are employed. Considering supply chain cost as average cost in this case is critical for the company, focus is on the analysis of solutions that keep the average cost at its best. Below given Tables 7-9 shows the different solutions obtained at different GA parameters. It exhibits the distribution of the best-so-far optimal solutions with a demand fill-rate higher than 90%. We

summarize several important solutions from these tables. We note that the solutions in the best-so-far solutions set are composed of basically two categories of supply chain network structures.

TABLE7: SCM STRUCTURE FOR POP SIZE 10 & 1000GENERATION

S1	S	S	S	S	S	S	S	S	ROP	Q	SP	F1
L1	1	1	2	2	2	2	3	4				
1	L	L	L	L	L	L	L	L				
	12	13	21	22	23	3	3	4				
70	16	14	0	0	0	0	0	0	6351	1652	365	20.2

TABLE8: SCM STRUCTURE FOR POP SIZE 100 & 1000GENERATION

S1	S	S	S	S	S	S	S	S	ROP	Q	SP	F1
L1	1	1	2	2	2	2	3	4				
1	L	L	L	L	L	L	L	L				
	12	13	21	22	23	3	3	4				
56	17	15	0	0	12	0	0	0	6351	1652	365	19.56

TABLE9: SCM STRUCTURE FOR POP SIZE 10 & 500GENERATION

S	S	S	S	S	S	S	S	S	ROP	Q	SP	F1
L	1	1	2	2	2	2	3	4				
11	L	L	L	L	L	L	L	L				
	12	13	21	22	23	3	3	4				
43	35	11	0	0	11	0	0	0	6351	1652	365	19.29

B. Result Analysis

We run the optimizer for different generations as 1000 and 500 respectively with a population size of at 10 and 100 respectively. The possibilities of crossover and mutation are set as 0.9 and 0.1, respectively. Roulette wheel selection and random one-point crossover are employed. Each of the points represented on the specific solution. In the results obtained integers (example in Table 8): values 56 and 17 under S1L11 and S1L12 respectively indicate that 56 % and 17 % of the total ordered quantity will be supplied through the respective modes. According to the Table 8 the SCN will comprise of supplier 1 and supplier 2, at the same time first and second transportation modes of supplier 2 will not be employed.

We summarize several important solutions in above given tables, we note that the solutions in the best-so-far set are composed of basically two categories of supply chain network structures. Suppliers S1 and S2 are advisable also the L22 mode of the supplier two is not utilized. The cost obtained will be approximately 19 £. The penalty cost is assumed to be 2.5£ per piece. Also result shows for a demand fill rate above 90 percent also at more a time employs the suppliers S1 and S2 since they can supply at better performance.

The variation pattern in the result is obtained due to the introduction of penalty cost as well as the newly introduced damage cost i.e. If better transportation is

used although their cost is bit high it can be effectively saved by avoiding the penalty cost and damage cost.

The proposed heuristic method has been coded in MATLAB. While we look about the algorithm the results obtained at different convergence i.e. the results obtained at 1000, 500 and with population sizes of 10 and 100 are exhibiting almost same solutions. It is mainly due to the way of iterations conducted. At each genetic operation the percentage allocation of product supplied by each supplier also gets iterated inside the program simultaneously. This enables the algorithm to search for more result at lesser generations which can save the time of simulation.

VII.CONCLUSION

An overview of a simulation based assessment and optimization of enterprise networks has been provided. In addition, the method was applied to a real life case study proposed by a textile industry. It was shown, that the method can be helpful for finding solutions for big business enterprises that have to get into the market at lesser time. Because the dynamic of a system comprising a huge number of more or less independent acting self-controlled entities within a network is hardly to predict and evaluate in real operation, appropriate tools are required for this purpose. Beside an assessment of the overall network, other aspects related to individual facilities or entities like specific control strategies could be tested and improved by using such a method. Due to its open and flexible architecture, this algorithm seems to be a perfect base for an adaptation/enhancement necessary in order to support such scenarios as well. Some benchmarking works are also to be done for approach performance assessment, comparing to the results obtained by analytical methods.

The present work provides a new insight to the practitioner to solve the different combinatorial problems e.g. network optimization in the supply chain context. The network optimization in the flexible supply chain context is a very complex problem for the practitioners.

The algorithm mainly emphasizes on the initialization, selection and genetic operators.

This research has enlightened the domain of supply chain network optimization as it discusses about the commitment of faster delivery at minimum cost. The managers can apply the solutions with providing more constraints accordance with the environment of the market and supply chain. The network optimization problem can also give a new vision to the managers of supply chain to achieve the solution in such a way that can fulfill the demand of the customer with minimum average cost per product. Therefore, it will provide a two dimensional approach at the same time. This research provides a new insight about the optimization

algorithms in theoretical manner but it can be employed in real industry problems also with some new constraints and the numerical analysis proved the same concept. As a future work, this research can be stretched out to various problems of the supply chain environment that having multi- product scenarios. This research can also be employed for JIT or flexible manufacturing situations where multi objectives goal are present.

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