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Full Length Research Paper

Supply Chain Optimization Model under Uncertainty

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Abstract

The supply-chain is an integrated effort by a number of entities - from suppliers of raw materials to producers, to the distributors - to produce and deliver a product or a service to the end user. Planning and managing a supply chain involves making decisions which depend on estimations of future scenarios (about demand, supply, prices, etc). Not all the data required for these estimations are available with certainty at the time of making the decision. The existence of this uncertainty greatly affects these decisions. If this uncertainty is not taken into account, and nominal values are assumed for the uncertain data, then even small variations from the nominal in the actual realizations of data can make the nominal solution highly suboptimal. The problem of design, analysis and optimization under uncertainty is central to decision support systems, and extensive research has been carried out in both Probabilistic (Stochastic) Optimization and Robust Optimization (constraints) frameworks. In this work, overview of previously published works on incorporating demand uncertainty in midterm planning of multisite supply chains has been taken. The proposed model provides an effective tool for evaluating and actively managing the exposure of an enterprises asset (such as inventory levels and profit margins) to market uncertainties. .In this research literature problem of one organization which has 3 sites of production has been taken. The problem consists of 3 sites. A total of 10 products which are grouped into 5 part families are manufactured which are characterized by different processing and cost attributes. The model consists of 5 constraints, 10 variable and 14 parameters. The model is solved manually to 3 iterations to optimal but as this process is time consuming so for this we have to develop the software. The problem formula is solved using genetic algorithm and programming of 'c' language. The simplex method is also used to make the problem formula to optimal.

Keywords: Supply chain, Uncertainty, Optimization, Simplex method, Genetic algorithm

Introduction

A supply chain consists of all parties involved directly or indirectly in fulfilling a customer request. The supply chain includes not only manufacturers and suppliers but also transporters, warehouses, retailers and even customer themselves Fig1 (Hugos, 2011). Within each organisation such as manufacturer the supply chain includes all functions involved in receiving and filling a customer request. These functions include but are not limited to new product development, marketing, operations, distribution, and finance and customer service.

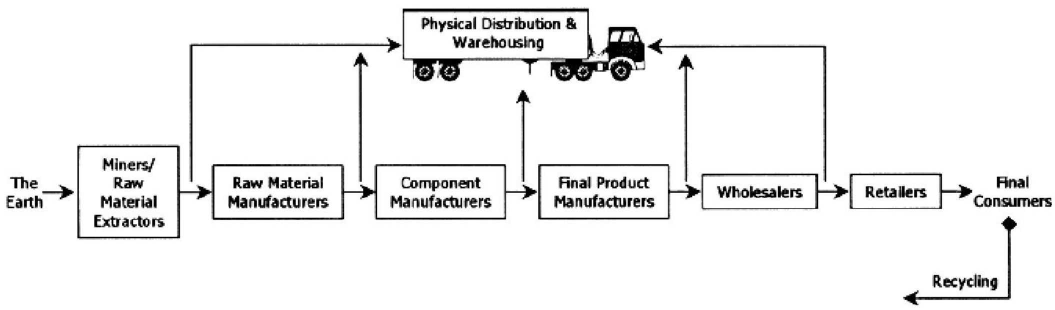

Fig 1: Activities and firms in a supply chain

In addition to defining the supply chain, several authors have further defined the concept of supply chain management. As defined by Ell ram and Cooper [1] (1993), supply chain management is "an integrating philosophy to manage the total flow of a distribution channel from supplier to ultimate customer". They believe that supply chains, not firms, compete and that those who will be the strongest competitors are those that "can provide management and leadership to the fully integrated supply chain including external customer as well as prime suppliers, their suppliers, and their suppliers' suppliers".

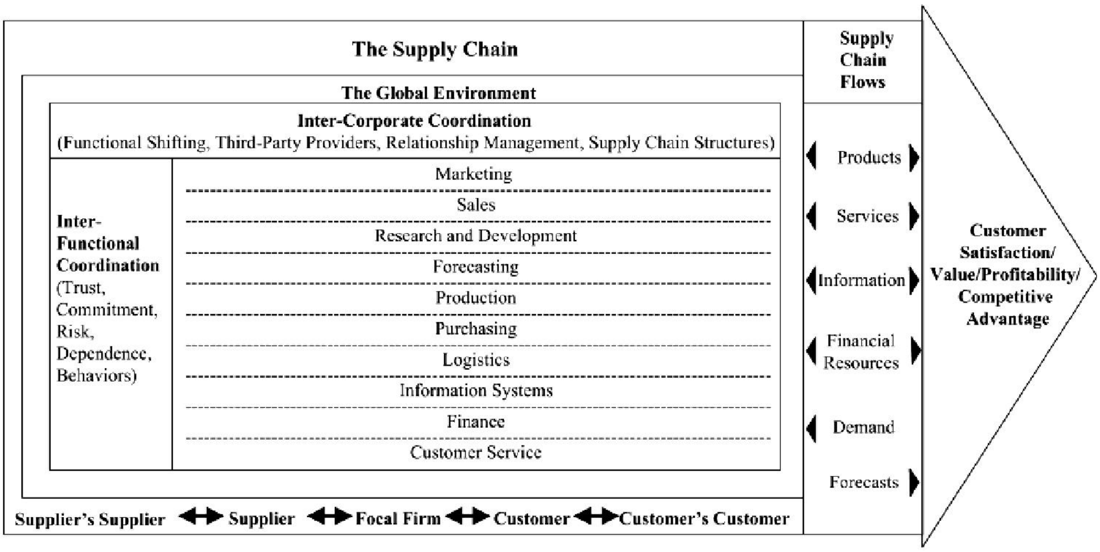

Fig 2: Supply chain management flow diagram

The supply chain begins with a need for a computer. In this example, a customer places an order for a Dell computer through the Internet. Since Dell does not have distribution centres or distributors, this order triggers the production at Dell's manufacturing centre, which is the next stage in the supply chain. Microprocessors used in the computer may come from AMD and a complementary product like a monitor may come from Sony. Dell receives such parts and components from these suppliers, who belong to the up-stream stage in the supply chain. After completing the order according to the customer's specification, Dell then sends the computer directly to the users through UPS, a third party logistics provider.

The impact of Collaborative Transportation Management on supply chain Performance: A simulation approach (Felix T.S. Chan, T. Zhang DATED, 2011) Collaborative Transportation Management (CTM) is based on the interaction and collaboration between trading partners and carriers participated in the supply chain, appropriate application of CTM can improve the flexibility in the physical distribution and minimize the inefficiency of supply chain management. This paper proposes new concepts of CTM and carriers' flexibility. A simulation approach is used to (i) evaluate the benefits of the proposed CTM, (ii) explain the concept of carrier's flexibility, and (iii) optimize the delivery speed capability. Based on a simple supply chain including one retailer and one carrier, three different simulation models have been developed with changeable delivery lead time as follows: (1) Unconstrained delivery speed capability without CTM. (2) Constrained delivery speed capability without CTM; and (3) Constrained delivery speed capability with CTM. Simulation results reveal that CTM can significantly reduce the retailer's total costs and improve the retailer's service level. Giri 2011(*3*) reported a single-product single-period inventory model in which the retailer can source from two suppliers in which the risk-averse retailer faces yield uncertainty from the primary supplier; the secondary supplier being reliable though capacity constrained. assumptions of two unreliable suppliers instead of one and/or other uncertainties such as demand and suppliers' lead time uncertainties would be worthful contributions. Qahtani et al *(2)* 2010 reported two-stage stochastic MILP model for designing an integration strategy under uncertainty and plan capacity expansions, as required, in a multisite refinery network. Robustness is analyzed based on model robustness and solution robustness, where each measure is assigned a scaling factor to analyze the sensitivity of the refinery plan and integration network due to variation.

In this research, I have taken a literature problem of one organization which has 3 sites of production. The problem consists of 3 sites. A total of 10 products which are grouped into 5 part families are manufactured which are characterized by different processing and cost attributes. The model consists of 5 constraints, 10 variable and 14 parameters. The model is solved manually to 3 iterations to optimality but as this process is time consuming so for this we have to develop the software. The extended work is described in the next section.

Methodology

Simplex Method

"Simplex method is considered one of the basic techniques from which many linear programming techniques are directly or indirectly derived. The simplex method is an iterative, stepwise process which approaches an optimum solution in order to reach an objective function of maximization or minimization" (Kumar, 2009).

Optimization

"Optimization is the term often used for minimizing or maximizing a function. It is sufficient to consider the problem of minimization only; maximization of F(x) is achieved by simply minimizing −F(x). In engineering, optimization is closely related to design. The function F(x), called the merit function or objective function, is the quantity that we wish to keep as small as possible, such as the cost or weight. The components of x, known as the design variables, are the quantities that we are free to adjust. Physical dimensions (lengths, areas, angles, etc.) are common examples of design variables. The optimization is very vast and many types of explanations are provided to it but the best way, in limited space is to introduce a few basic methods that are good enough for problems that are reasonably well behaved and do not involve too many design variables.

The algorithms for minimization are iterative procedures that require starting values of the design variables x. If F(x) has several local minima, the initial choice of x determines which of these will be computed. There is no guaranteed way of finding the global optimal point. One suggested procedure is to make several computer runs using different starting points and pick the best result. More often than not, the design is also subjected to restrictions, or constraints, which may have the form of equalities or inequalities" (Geunes et al, 2005).

Genetic algorithm
"The concept of GA was developed by Holland and his colleagues in the 1960s and 1970s. GA is inspired by the evolutionist theory explaining the origin of species. In nature, weak and unfit species within their environment are faced with extinction by natural selection. The strong one shaves greater opportunity to pass their genes to future generations via reproduction. In the long run, species carrying the correct combination in their genes become dominant in their population. Sometimes, during the slow process of evolution, random changes may occur in genes. If these changes provide additional advantages in the challenge for survival, new species evolve from the old ones. Unsuccessful changes are eliminated by natural selection. The procedure of a generic GA is given as follows:

A. *Step.1:* The objective function should be defined which has to be minimized. It must be in form of #.M file and should return a scalar value.
B. *Step.2:* Population: generates the population and mention the population size that specifies how many individuals there are in each generation.
C. *Step.3:* Fitness value: is defined for each population.
D. *Step.4:* Scaling: tournament selection is used for fitness scaling. In tournament fitness scaling the each parent is selected by choosing individual at random. Number of parent selected can be specified by the tournament size. The best parent is selected out of the formed set.
E. *Step.5:* Reproduction: option for genetic algorithm creates children at each new generation. It is done by elite count and crossover fraction. In elite count the number of individuals that are generated to survive the next generation whereas crossover determines the fraction of next generation that the crossover produces.
F. *Step.6:* Crossover: It is used to combine two individual or parent to form a new individual or child. The parents are selected among existing chromosomes in the population with preference towards fitness so that offspring is expected to inherit good genes which make the parents fitter. By iteratively applying the crossover operator, genes of good chromosomes are expected to appear more frequently in the population, eventually leading to convergence to an overall good solution.
G. *Step.7:* Migration: is the movement of individuals between the subpopulation which is the algorithm creates. It can be forward, backward or both ways in direction.
H. *Step.8:* Mutation: The mutation operator introduces random changes into characteristics of chromosomes. Mutation is generally applied at the gene level. In typical GA implementations, the mutation rate (probability of changing the properties of a gene) is very small and depends on the length of the chromosome. Therefore, the new chromosome produced by mutation will not be very different from the original one. Mutation plays a critical role in GA. As discussed earlier, crossover leads the population to converge by making the chromosomes in the population alike. Mutation reintroduces genetic diversity back into the population and assists the search escape from local optima.
I. *Step.8:* Hybrid function: No hybrid function is used.
J. *Step.9 :*(Termination): Output is give as the set containing non-dominated solutions when the termination criteria is met otherwise again the process to be repeated from evaluation of function" (Sivanandam et al, 2007).

Multi-Objective Genetic Algorithm
The objective function of formulation is composed of two terms. The first term subjected to the outer optimization problem constraints accounts for the cost incurred in the production stage. Second term Z quantities the costs of the logistics decisions and is obtained by applying the expectation operator to an embedded optimisation problem.

"Being a population-based approach, GA is well suited to solve multi-objective optimization problems. A generic single-objective GA can be modified to find a set of multiple non dominated solutions in a single run. The ability of GA to simultaneously search different regions of a solution space makes it possible to find a diverse set of solutions for difficult problems with non convex, discontinuous, and multi-modal solutions spaces. The crossover operator of GA may exploit structures of good solutions with respect to different objectives to create new non dominated solutions in unexplored parts of the Pareto front. In addition, most multi-objective GA does not require the user to prioritize, scale, or weigh objectives. Therefore, GA has been the most popular heuristic approach to multi-objective design and optimization problems" (. (Jones et al., 1998) reported that 90% of the approaches to multi-objective optimization aimed to approximate the true Pareto front for the underlying problem. A majority of these used a meta-heuristic technique and 70% of all met heuristics approaches were based on evolutionary approaches.

Extended work

For the formulation various indices are:

- *i= set of products*
- *f= set of product families*
- *j= set of processing equipment*
- *s= set of production sites*

Parameters:

- FC_{fs} = *setup cost for family f at site s*
- v_{ijs} = *variable production cost for product i on unit j at site s*
- p_{is} = *price of raw material i at site s*
- $t_{iss'}$ = *inter-site transportation cost form site s to site s'*
- t_{is} = *customer-site transportation cost*
- Z_{is} = *safety stock violation penalty for product i at site s*
- J_i = *revenue per unit of product i sold to customer c*
- MRL_{fis} = *minimum run length for family f on unit at site s*
- H_{fjs} = *total available processing time*
- R_{ijs} = *rate of production of product i on unit j at site s*
- $\beta_{i'is}$ = *yield adjusted amount of product i consumed to produce product i'*
- I^o_{is} = *initial inventory*
- I^L_{is} = *safety stock level for product i at site s*
- θ_i = *uncertain demand*

Variables:

- A_{is} = *availability of product i for supply at site s*
- P_{ijs} = *production amount of product i on unit j at site s*
- RL_{ijs} = *run length of product i on unit j at site s*
- C_{is} = *raw material consumption of product i at site s*
- $W_{is's}$ = *intersite shipment of product from site s to site s'*
- Y_{fjs} = *setup (binary variables indicating whether product family f is manufactured on unit j at site s).*
- S_{is} = *supply of product*
- I_{is} = *inventory of product*
- I_{is}^{Δ} = *deviation below safety stock of product*
- I_{is}^{-} = *customer shortage*

Mathematical model

The supply chain formulation is taken from Gupta and Maranas [2003] as reference for the work:

$$\text{Min} \quad \sum_{f,j,s} FC_{fs} Y_{fjs} + \sum_{i,j,s} v_{ijs} P_{ijs} + \sum_{i,s} p_{is} C_{is} + \sum_{i,s,s'} t_{iss'} W_{iss'} + Z$$

p_{ijs} RL_{ijs} FRL_{fjs}
A_{is} C_{is} $W_{iss'} \geq 0$
Y_{fjs} €{0,1}

$$Z = E_{\theta_i}\left[\begin{array}{lll} \min & \sum_{i,s} t_{is} S_{is} + \sum_{i,s} h_{is} I_{is} + \sum_{i,s} Z_{is} I_{is}^{\Delta} + \sum_{i} J_i I_i' & \\ S_{is}, I_{is}, I_{is}^{\Delta}, I_{is}' \geq 0 & & \\ & \sum_{s} S_{is} \leq \theta_i & ...(a) \\ & I_{is} = A_{is} - S_{is} & ...(b) \\ & \theta_i - \sum_{s} S_{is} \leq I_i' \leq \theta_i & ...(c) \\ & I^L_{is} - I_{is} \leq I^{\Delta}_{is} \leq I_{is}^L & ...(d) \end{array}\right]$$

Subject to

$$P_{ijs} = R_{ijs} RL_{ijs} \qquad \text{...(1)}$$

$$C_{is} = \sum_{i'} \beta_{ii's} \sum_{j} P_{i'js} = \sum_{s'} W_{is's} \qquad \text{...(2)}$$

$$A_{is} = I_{is}^{\Delta} + \sum_{j} P_{ijs} + \sum_{s'} W_{iss'} \qquad \text{...(3)}$$

$$\sum_{f} \sum_{i:\lambda_{if}=1} RL_{ijs} \le H_{fjs} \qquad \text{...(4)}$$

$$MRL_{fjs} Y_{fjs} \le \sum_{i:\lambda_{if}=1} RL_{ijs} \le H_{fjs} Y_{fjs} \qquad \text{...(5)}$$

The objective function of the deterministic midterm planning captures the combined costs incurred in the manufacturing and logistics phases. The manufacturing phase costs include fixed and variable production charges, cost of raw material purchase and transportation charges incurred for the intersite shipment of intermediate products. The subsequent logistics phase costs are comprised of the transportation charges incurred for shipping the final product to the customer, inventory holding charges, safety stock violation penalties and penalties for lost sales. The decisions made in the manufacturing phase establish the location and timing of production runs, length of campaigns, production amounts and consumption of raw materials. Specifically, Pijs , RLijs , FRLfjs , Ais , Cis , Wiss' and Yfjs constitute the manufacturing variables , and uniquely define the production levels and resource utilizations in the supply chain.

- These manufacturing variables are constrained by the manufacturing constraints given by Eqs. (1)_(5).
- The production amount of a particular product is defined in terms of the rate of production and the campaign run length by Eq. (1).
- The input-output relationships between raw materials and final products, accounting for the bill-of-materials and redundancy in the intersite shipment of intermediate products is eliminated by Eq. (2), which forces the products shipped to a particular site in a particular period to be consumed in the same period.
- The allocation of products to product families is achieved. Grouping of products into product families is typically done to account for the relatively small transition times and costs between similar products. Eq. (4) models the capacity restrictions while Eq. (5) provides upper and lower bounds for the family run lengths.
- The amount available for supply in the logistics phase following the manufacturing phase is defined through Eq. (3).
- The decisions made in the logistics phase, termed the logistics variables, are Sis, Iis, I_{is}^{Δ},I^{L}_{is}. The corresponding logistics constraints are given by Eqs. (a)_(d).
- The linking between the manufacturing and logistics phases is captured by Eq. (b). The inventory level, which is determined by the amount available for supply and the actual supplies to the various customers, is defined by Eq. (b).
- No overstocking is permitted at the customer (Eq. (a))
- The customer shortages are carried over time (Eq. (c)). Eq. (d) models the violation of the safety stock levels.

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Updated Work

Solving the objective function by Simplex method:

$$\text{Min} \quad \sum_{f,j,s} FC_{fs} Y_{fjs} + \sum_{i,j,s} v_{ijs} P_{ijs} + \sum_{i,s} p_{is} C_{is} + \sum_{i,s,s'} t_{iss'} W_{iss'} + Z$$

p_{ijs} RL_{ijs} FRL_{fjs}
A_{is} C_{is} $W_{iss'}$ ≥ 0
Y_{fjs} €{0,1}

$$Z = E_{\theta_i} \left[\begin{array}{ll} \min\limits_{S_{is}, I_{is}, I_{is}^{\Delta}, I_{is}' \ge 0} & \sum_{i,s} t_{is} S_{is} + \sum_{i,s} h_{is} I_{is} + \sum_{i,s} Z_{is} I_{is}^{\Delta} + \sum_{i} J_i I_i' \\ & \sum_{s} S_{is} \le \theta_i \\ & I_{is} = A_{is} - S_{is} \\ & \theta_i - \sum_{s} S_{is} \le I_i' \le \theta_i \\ & I^{L}_{is} - I_{is} \le I^{\Delta}_{is} \le I_{is}^{L} \end{array} \right]$$

$$\sum_{f,j,s} FC_{fs}Y_{fjs} + \sum_{i,j,s} v_{ij}P_{ijs} + \sum_{i,s} p_{is}C_{is} + \sum_{i,s,s'} t_{iss'}W_{iss'} + Z$$

$$= \sum_{f,j,s} FC_{fs}Y_{fjs} + \sum_{i,j,s} v_{ij}R_{ijs}RL_{ijs} + \sum_{i,s} p_{is} \sum_{i,s,s'} W_{iss'} + \sum_{i,s,s'} t_{iss'}W_{iss'} + Z$$

$$= \sum_{f,j,s} FC_{fs}Y_{fjs} + \sum_{i,j,s} v_{ij}R_{ijs}RL_{ijs} + \sum_{i,s} p_{is} \sum_{i,s,s'} W_{iss'} + \sum_{i,s,s'} t_{iss'} \sum_{i,s,s'} W_{iss'} + Z$$

$$= \sum_{f,j,s} FC_{fs}Y_{fjs} + \sum_{i,j,s} v_{ij}R_{ijs}RL_{ijs} + \sum_{i,s,s'} W_{iss'} \left(\sum_{i,s} p_{is} + \sum_{i,s,s} t_{iss'} \right) + Z$$

$$= \sum_{f,j,s} FC_{fs}Y_{fjs} + \sum_{i,f,j,s} v_{ij}R_{ijs}H_{fjs} + \sum_{i,s,s'} W_{iss'} \left(\sum_{i,s} p_{is} + \sum_{i,s,s} t_{iss'} \right) + Z$$

$$= FC_{1fs}Y_{fjs} + v_{1ij}\, R_{1ijs}H_{1fjs} + W_{1iss'}\left(p_{1is} + t_{1iss'}\right) + Z \qquad ...(1)$$

$now\, again$

$$Z = E_{\theta i}\left[\begin{array}{ll} \min\limits_{S_{is}, I_{is}, I_{is}^{\Delta}, I_{is}' \geq 0} & \sum_{i,s} t_{is}S_{is} + \sum_{i,s} h_{is}I_{is} + \sum_{i,s} K_{is}I_{is}^{\Delta} + \sum J_i I_i' \\ & \sum_{s} S_{is} \leq \theta_i \\ & I_{is} = A_{is} - S_{is} \\ & \theta_i - \sum_{s} S_{is} \leq I_i' \leq \theta_i \\ & I^{L}_{is} - I_{is} \leq I^{\Delta}_{is} \leq I_{is}^{L} \end{array}\right]$$

$$\sum_{i,s} t_{is}S_{is} + \sum_{i,s} h_{is}I_{is} + \sum_{i,s} K_{is}I_{is}^{\Delta} + \sum_{i} J_i I_i'$$

$$= \sum_{i,s} t_{is}\theta_i + \sum_{i,s} h_{is}I_{is} + \sum_{i,s} K_{is}I_{is}^{\Delta} + \sum_{i} J_i I_i'$$

$$= \sum_{i,s} t_{is}\theta_i + \sum_{i,s} h_{is}\left(A_{is} - S_{is}\right) + \sum_{i,s} K_{is}I_{is}^{\Delta} + \sum_{i} J_i I_i'$$

$$= \sum_{i,s} t_{is}\theta_i + \sum_{i,s} h_{is}\left(A_{is} - S_{is}\right) + \sum_{i,s} K_{is}\left(I_{is}^{L} - I_{is} + 0\right) + \sum_{i} J_i I_i'$$

$$= \sum_{i,s} t_{is}\theta_i + \sum_{i,s} h_{is}\left(A_{is} - S_{is}\right) + \sum_{i,s} K_{is}\left(I_{is}{}^{L} - I_{is}\right) + \sum_{i} \mu_i I_i{}'$$

$$= t_{1is}\theta_1 + h_{1is}(A_{1is} - S_{1is}) + K_{1is}(I_{1is}{}^{L} - I_{is}) + \mu_1 I_{1i}{}'$$

$$putting\ value\ of\ Z\ in\ eq1$$

$$= FC_{1fs}Y_{fjs} + v_{1ij}\ R_{1ijs}H_{1fjs} + W_{1iss'}\left(p_{1is} + t_{1iss'}\right) + [t_{1is}\theta_1 + h_{1is}(A_{1is} - S_{1is}) + K_{1is}(I_{1is}{}^{L} - I_{is}) + J_1 I_{1i}{}'] \qquad \ldots(2)$$

Results and Discussion

The objective was to optimize the supply chain under uncertainty as developed in mathematical model. The overall function includes uncertainty along with parameters like;

i. Transportation factor which includes supply due to uncertain demand with customer site transportation cost (A).
ii. Holding cost includes inventory and the holding cost associated with it (B).
iii. Deficit safety stock penalty factor includes the safety stock violation penalty and deficit in the safety stock (C).
iv. Revenue loss factor consist of the lost revenue cost and the customer shortage (D).
v. Production cost factor includes the set up cost with the variable production cost in producing certain amount (E).
vi. Raw material cost includes the cost along with the consumption of raw material (F).
vii. Inter-site transportation cost includes the shipment cost along the site (G).

The developed model was solved into two stages. In first stage uncertainty parameter were optimized then the optimized parameter of uncertainty was called in main function to get the final optimized value of objective function. The model was solved using both hard computing and soft computing tool. For hard computing an algorithm was developed in C using simplex. Whereas for soft computing Matlab was used as a platform for solving problem using genetic algorithm. The model was solved using above methodology for different case as discussed later in the chapter.

Input Data

The data used to validate the model developed have been considered from the literature and the optimization has been done using the same.

Table 1: Input parameters for case studies

Parameter	Notation	Value at site 1	Value at site 2	Value at site 3
Fixed cost	FC_{fs}	4.5,4.8,5.5,6.2,4.5	6.5,3.5,6.5,4.5,6.5	6.5,5.2,5.1,4.7,6.5
Set up	Y_{fjs}	1	1	1
Variable production cost	v_{ijs}	2.5	2.3	2.6
Raw material cost	P_{is}	10	15	20
Inter-site transportation cost	$t_{iss'}$	1	2	4
Customer site transportation cost	t_{is}	1.1	1.2	1.3
Inventory holding cost	h_{is}	1.8	1.7	1.6
Production amount	P_{ijs}	10	15	20
Raw material consumption	C_{is}	5	10	20
Inter-site shipment	$W_{iss'}$	1	3	6
Supply under uncertain demand	S_{is}	70	100	110
Inventory	I_{is}	10	10	15
Safety stock violation	K_{is}	2.7	2.3	2.2
Safety stock deficit	$I_{is}{}^{\Delta}$	10	15	25
Customer shortage	I_i^-	1	2	3
Lost revenue cost	J_i	10	9	9.5

The values are considered from the above table and considering the given 3 sites as discussed in the problem environment. The developed model was solved using the aforesaid method and was validated for 3 sites taken as case studies.

CASE 1: SITE 1

Results from programming C

```
ENTER NO. OF SITES:3

ENTER VALUES

ENTER setup[Yfjs]:1

ENTER variable production cost[Vijs]:2.5

ENTER production amount[Pijs]:10

ENTER raw material cost[pis]:10

ENTER raw material consumption[Cis]:5

ENTER intersite transportation cost[Tiss]:1

ENTER intersite shipment[Wiss]:1

ENTER customer site transportation cost[Tis]:1.1

ENTER inventory holding cost[his]:1.8

ENTER inventory[Iis]:10
```

Fig 3: Output (a) for Site 1

```
ENTER inventory[Iis]:10

ENTER THE VALUE OF SAFETY STOCK:2.7

ENTER THE VALUE OF STOCK DEFICIATE:10

ENTER THE VALUE OF LOST REVENUE COST:10

ENTER THE VALUE OF CUSTOMER SHORTAGE:1

 SITE 1

ENTER FCfs:4.5

ENTER Sis:70

 RESULT:217.500000
ENTER FCfs:4.8

ENTER Sis:50

 RESULT:195.800003
ENTER FCfs:5.5

ENTER Sis:85
```

Fig 4: Output (b) for site 1

```
 RESULT:217.500000
ENTER FCfs:4.8

ENTER Sis:50

 RESULT:195.800003
ENTER FCfs:5.5

ENTER Sis:85

 RESULT:235.000000
ENTER FCfs:6.2

ENTER Sis:100

 RESULT:252.199997
ENTER FCfs:4.5

ENTER Sis:100

 RESULT:250.500000
THE MINIMUM RESULT IS:195.800003
```

Fig 5: Output (c) for site 1

Taking different values for the different iterations of the values for site 1 the result is 195.80003

Result from GA at Site 1.

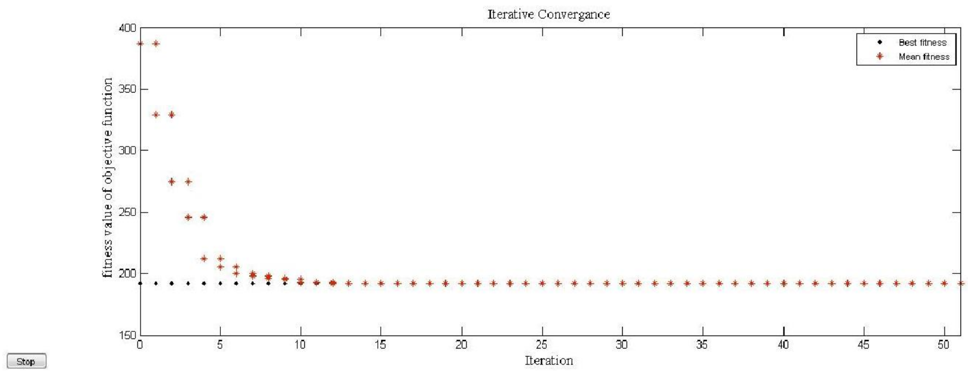

Fig 6: Fitness value of objective function for site 1

The Fig 6 shows the iterative convergence of objective function towards optimal value. As the iteration starts with initial value and becomes constant from iteration 14 and the value stabilizes for later iterations at 191.

Table 2: Optimized values for site 1

Parameter	Notation	Optimized Value	Optimized value of objective function
Transportation cost	A	75	
Holding cost	B	15	
Deficit Safety stock	C	25	191.7738
Revenue Loss factor	D	8	
Production cost	E	25	
Raw Material Cost	F	43	
Inter-site transportation	G	.774	

Comparing the both results as the model was solved with help of both hard computing and soft computing the result from GA is more optimized then the result of other. As hard computing provides the crisp value taking the crisp data & the soft computing the fuzzy values are taken so which provide better result. The optimum value from the C Program (hard computing) is 195.8003 whereas the GA (Soft computing) provides the result as 191.7738. As the optimal sequence was generated by the GA for each problem, the problem was repeatedly run for more times to ensure the consistency of the solution and the mean of optimization. In C the search space is less whereas in GA the search space is comparatively more.

CASE 2: SITE 2

RESULTS FROM C

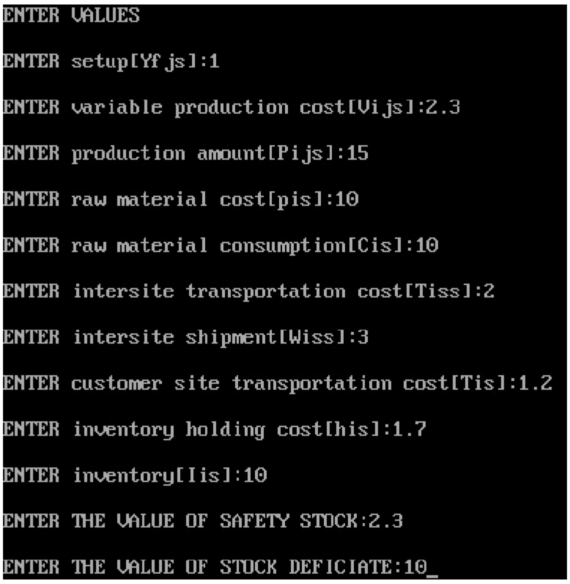

Fig 7: Output (a) for site 2

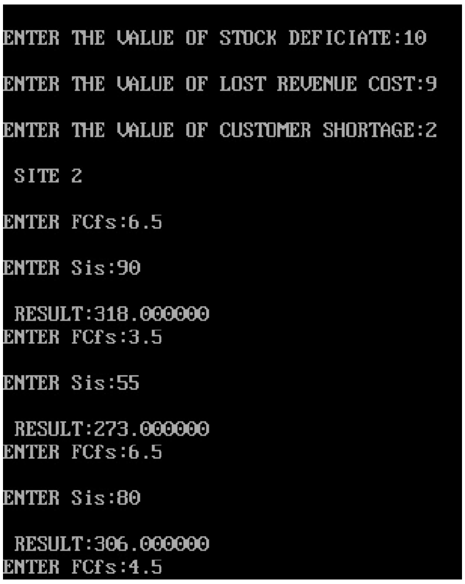

Fig 8: Output (b) for site 2

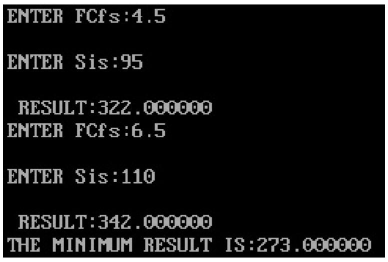

Fig 9: Output (c) for site 2

Taking different values for the different iterations of the values for site 2 the result is 273.000

Result from GA at Site 2

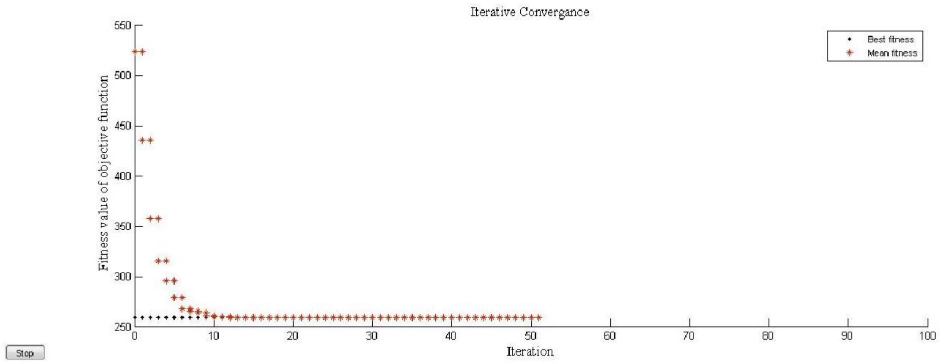

Fig 10: Fitness Value of objective function at site 2

Fig 10 shows the iterative convergence of objective function towards optimal value. As the iteration starts with initial value and becomes constant from iteration 12 and the value stabilizes for later iterations at 259.

Table 3: Optimized values for site 2

Parameter	Notation	Optimized Value	Optimized value of objective function
Transportation cost	A	121	
Holding cost	B	18	
Deficit Safety stock	C	27	259.3007
Revenue Loss factor	D	11	
Production cost	E	31	
Raw Material Cost	F	50	
Inter-site transportation	G	1.301	

Comparing the both results as the model was solved with help of both hard computing and soft computing the result from GA is more optimized then the result of other. As hard computing provides the crisp value taking the crisp data & the soft computing the fuzzy values are taken so which provide better result. The optimum value from the C Program (hard computing) is 273 whereas the GA (Soft computing) provides the result as 259.3007. As the optimal sequence was generated by the GA for each problem, the problem was repeatedly run for more times to ensure the consistency of the solution and the mean of optimization

CASE 3: SITE 3

RESULTS FROM C

```
ENTER setup[Yfjs]:    1
ENTER variable production cost[Vijs]:2.6
ENTER production amount[Pijs]:20
ENTER raw material cost[pis]:15
ENTER raw material consumption[Cis]:10
ENTER intersite transportation cost[Tiss]:4
ENTER intersite shipment[Wiss]:6
ENTER customer site transportation cost[Tis]:1.3
ENTER inventory holding cost[his]:1.6
ENTER inventory[Iis]:15
ENTER THE VALUE OF SAFETY STOCK:2.2
ENTER THE VALUE OF STOCK DEFICIATE:25_
```

Fig 11: Output (a) for site 3

```
ENTER THE VALUE OF STOCK DEFICIATE:25
ENTER THE VALUE OF LOST REVENUE COST:9.5
ENTER THE VALUE OF CUSTOMER SHORTAGE:3
 SITE 3
ENTER FCfs:6.5
ENTER Sis:70
 RESULT:436.000000
ENTER FCfs:4.8
ENTER Sis:50
 RESULT:408.299988
ENTER FCfs:5.5
ENTER Sis:85
 RESULT:454.500000
ENTER FCfs:6.2
```

Fig 12: Output (b) for site 2

```
ENTER FCfs:6.2

ENTER Sis:100

 RESULT:474.699982
ENTER FCfs:4.5

ENTER Sis:100

 RESULT:473.000000
THE MINIMUM RESULT IS:408.299988
```

Figure 13: Output (c) for site 3

Taking different values for the different iterations of the values for site 3 the result is 408.2999

Result of GA at Site 3

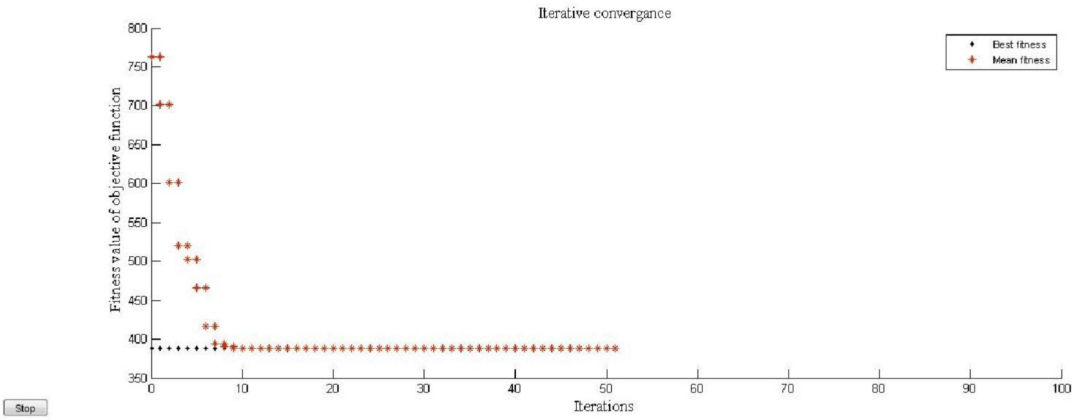

Fig 14: Fitness value for objective function at site 3

Fig 14 shows the iterative convergence of objective function towards optimal value. As the iteration starts with initial value and becomes constant from iteration 10 and the value stabilizes for later iterations at 388.

Table 4: Optimized values for site 3

Parameter	Notation	Optimized Value	Optimized value of objective function
Transportation cost	A	110	
Holding cost	B	18	
Deficit Safety stock	C	40	388
Revenue Loss factor	D	22	
Production cost	E	44	
Raw Material Cost	F	150	
Inter-site transportation	G	4	

Comparing the both results as the model was solved with help of both hard computing and soft computing the result from GA is more optimized then the result of other. As hard computing provides the crisp value taking the crisp data & the soft computing the fuzzy values are taken so which provide better result. The optimum value from the C Program (hard computing) is 403.2999 whereas the GA (Soft computing) provides the result as 388. As the optimal sequence was generated by the GA for each problem, the problem was repeatedly run for more times to ensure the consistency of the solution and the mean of optimization.

Summary and Conclusions

A supply chain consists of all parties involved directly or indirectly in fulfilling a customer request. The supply chain includes not only manufacturers and suppliers but also transporters, warehouses, retailers and even customer themselves. Within each organization such as manufacturer the supply chain includes all functions involved in receiving and filling a customer request. These functions include but are not limited to new product development, marketing, operations, distribution, and finance and customer service.

The problem associated with supply chain is Product demand variability which is a source of uncertainty in any supply chain. Failure to account for significant product demand fluctuation in the midterm by deterministic planning model may lead to excessively high production costs (translating to high inventory charges) or unsatisfied customer demand and loss of market share. Incorporation of demand uncertainty in midterm planning of multisite supply chains having (semi)continuous processing attributes is discussed as the trade off involved between the inventory depletion and production cost is face of uncertainty.

The mathematical model was developed for the relevant problem scenario. The objective function of formulation was composed for two terms. The first term subjected to the outer optimization problem constraints accounts for the cost incurred in the production stage. Second term Z quantities the costs of the logistics decisions and is obtained by applying the expectation operator to an embedded optimization problem.

The developed mathematical model was first solved using C program (Hard computing) but the hard computing finds the optimal solution using the crisp data and the search space is less. Then the model was solved with the help of Matlab as platform using Genetic Algorithm (Soft computing). As soft computing provides larger search space as compared to hard and uses fuzzy values which provides the better result. As the optimal sequence was generated by the GA for each problem, the problem was repeatedly run for more times to ensure the consistency of the solution and the mean of optimization.

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