Optimization of Supply Chain Network Using Genetic Algorithm

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Abstract

Optimization is the methodologies 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 most cost effective or highest achievable performance 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 it must manage and run profitably and efficiently to survive and grow. Managing the entire supply chain becomes a key factor for the successful business. In this work, the optimal solution of a supply chain networking is obtained by using the non-traditional technique such as genetic algorithm. The proposed genetic algorithm frame work offers a number of advantages like it is a multiple point search technique that examines a set of solutions and not just one solution. This article deals with the optimization of the supply chain network of an organization by reducing the total operating cost considering various constraints.

Keywords: Optimization, Suppliers, Supply chain network, operating cost, and genetic algorithm.

1 Introduction

The cost of quality is an increasingly important issue in the context of quality. There was a wrong opinion that achievement of better quality requires higher costs. Many Indian industries failed to invest more on quality cost related programs. Quality costs can help to quantify specific quality levels and ultimately improve productivity. Traditionally recommendations were made to management that a choice had to be made between quality and cost called the "trade-off decision. This is because better quality would somehow cost more and make production difficult. But it is not true. Good quality leads to increased production, reduced quality cost, increased sales and market penetration and hence higher profits. Deming states that improving quality can reduce the overall cost. A model is proposed to identify the different quality costs in the industry and is going to be implemented practically. But, theoretically it has been found hat some quality costs are more critical and require greater attention. Quality costing is an increasingly important issue in the field of quality. Traditionally recommendations were made to organization that a choice should be made between quality and cost called the trade-off decision. Because quality costs can help to quantify specific levels and improve productivity and also better quality, costs more and makes production difficult. Supply Chain Management can be best described as the natural extension of the downsizing (right-sizing) 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. These operations of downsizing and reengineering involved the optimization in terms of the number of persons involved, the time taken, the complexity of the work etc. of business units (functional and/or administrative domains) over which the organizations had full control. These strategies did lead to increased productivity and profitability of the organizations but as the benefits of these leveled off, it was realized that the approach to the way organizations work needed to be changed. The above changes were a by-product of the isolationist (closed system) world picture of the enterprises involved in the full value chain; with organizations (the system) trying to survive in an hostile environment; assuming that all other participants in the value chain were adversaries with whom the organization must compete, even though the operations performed by the separate organizations may be supplementary in nature rather than complementary. The present work deals with managing the supply chain network of an industry (case study) and reducing the total operating cost of the industry.

2 Literature review

2.1 Supply Chain Management

In today's competitive world, the success of an industry is contingent upon the management of its supply chain. Supply chain management is a relatively new term. It crystallizes concepts about integrated business planning that have been espoused by logistics experts, strategists, and operations research practitioners. Today, integrated planing is finally possible due to advances in information technology, but most companies still have much to learn about implementing new analytical tool needed to achieve it. In order to stay competitive and continue to survive they need to be their competitors. World class organizations now realize that non-integrated manufacturing process, non-integrated distribution process and poor relationship with suppliers and customers are inadequate for their success. Supply chains encompass a series of steps that add value through time, place, and material transformation. A typical supply chain network is given in fig.1

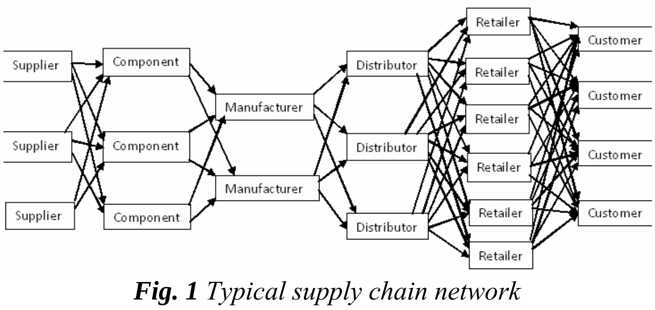

Fig. 1 *Typical supply chain network*

All organizations have or can purchase the components to build a supply chain network, it is the collection of physical locations, transportation vehicles and supporting systems through which the products and services your firm markets are managed and ultimately delivered. Physical locations included in a supply chain network can be manufacturing plants, storage warehouses, and carrier cross docks, major distribution centers, ports, and intermodal terminals whether owned by the company, the suppliers, the transport carrier, a third-party logistics provider, a retail store or the end customer. Transportation modes that operate within a supply chain network can include the many different types of trucks, trains for boxcar or intermodal unit movement, container ships or cargo planes. The systems which can be utilized to manage and improve a supply chain network include order management systems, warehouse management system, transportation management systems, strategic logistics modeling, inventory management systems, replenishment systems, supply chain visibility, optimization tools and more.

2.2 Genetic Algorithms

Genetic algorithms were formally introduced in the United States in the 1970s by John Holland at University of Michigan. The continuing price and performance improvements of computational systems have made them attractive for some types of optimization. In particular, genetic algorithms work very well on mixed (continuous and discrete), combinatorial problems. They are less susceptible to getting 'stuck' at local optima than gradient search methods. Genetic algorithms are implemented in a computer simulation in which a population of abstract representations called chromosomes or the genotype of the genome of candidate solutions called individuals, creatures, or phenotypes to an optimization problem gives better solutions. Traditionally, solutions are represented in binary as strings of 0s and 1s, but other encodings are also possible. The evolution usually starts from a population of randomly generated individuals and happens in generations. In each generation, the fitness of every individual in the population is evaluated, multiple individuals are stochastically selected from the current population (based on their fitness), and modified (recombined and possibly randomly mutated) to form a new population. The new population is then used in the next iteration of the algorithm. Commonly, the algorithm terminates when either a maximum number of generations has been produced, or a satisfactory fitness level has been reached for the population. If the algorithm has terminated due to a maximum number of generations, a satisfactory solution may or may not have been reached. Genetic algorithms find application in bioinformatics, phylogenetics, computational science, engineering, economics, chemistry, manufacturing, mathematics, physics and other fields. The Genetic algorithm implementation flow chart is given in fig.2

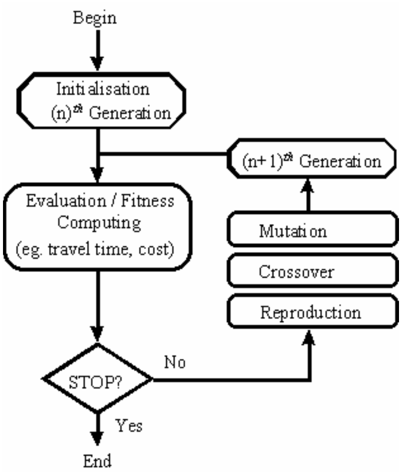

Fig. 2 *GA Implementation Flow Chart*

2.2.1 Simple generational genetic algorithm pseudo code:

1. Choose the initial population of individuals
2. Evaluate the fitness of each individual in that population
3. Repeat on this generation until termination: (time limit, sufficient fitness achieved, etc.)
   3.1. Select the best-fit individuals for reproduction
   3.2. Breed new individuals through crossover and mutation operations to give birth to offspring
   3.3. Evaluate the individual fitness of new individuals
   3.4. Replace least-fit population with new individuals

2.2.2 Benefits of Genetic Algorithm

1. Concept is easy to understand
2. Modular, separate from application
3. Supports multi-objective optimization
4. Good for noisy environments
5. Always an answer, answer gets better with time
6. Inherently parallel, easily distributed

3 Objective of the work

This work specifically deals with the modeling and opimization of a supply chain network using genetic algorithm. The four stages used in this article are suppliers, plants, distribution centers and retailer zones. This 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. This work deals with vendor assessment, minimizing the total operating cost and maximizing the profit of the industry with the help of a mathematical modeling. The modeling is done using genetic algorithm (MAT LAB) as optimizing tool for a four stage supply chain.

4 Description of the work

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 it must manage and run profitably and efficiently to survive and grow. Managing the entire supply chain becomes a key factor for the successful business. The model was mathematically represented considering the capacity, inventory balancing and demand constraints at various stages of the supply chain. The mathematical formulation was solved using genetic algorithm. The industry under study has the following details. The problem is to capture the dynamics of a single product being manufactured out of 3 different components.

- Suppliers - 3
- Manufacturing plants - 2
- Distribution centers - 3
- Retailer - 6

4.1 Techniques and software used

Techniques Used: GENETIC ALGORITHM
Software Used: MAT LAB 7.5
Genetic Algorithm Parameters:

Crossover fraction	=	20
Migration fraction	=	0.02
Population size	=	20
Generation	=	50

5 Problem definition

Equations of the Objective Functions and Contraints

The equations of the objective function is given in equaion (1) and the constraints are given in equations (2) to (6)

1. Total Operating Cost :
   $TOC = TC + SC + MC + DC$ (Eqn. 1)
2. Transportation cost (TC):
   $$TC = \sum_c \sum_s \sum_p \left(a_{c,s,p} \times TSP_{c,s,p} \right) + \sum_p \sum_d \left(b_{p,d} \times TPD \right) \quad \text{(Eqn. 2)}$$
3. Supplier cost(SC):
   $$SC = \sum_c \sum_s \left(CS_{c,s} \times a_{c,s,p} \right) \quad \text{(Eqn. 3)}$$
4. Manufacturer cost (MC):
   $$MC = \sum_p \left\{\left(M_p \right) \times \left(\sum_d b_{p,d} \right)\right\} + \left\{\sum_p \left(IC_p \times \sum_c I_{c,p} \right)\right\} \quad \text{(Eqn. 4)}$$
5. Distributors cost (DC):
   $$DC = \sum_d \sum_r \left(c_{d,r} \times TCD_{d,r} \right) + \sum_d \left(ICD_d \times ID_d \right) \quad \text{(Eqn. 5)}$$
6. Profit = $\left(\text{Demand} \times \text{Selling Price} \right) - TOC$ (Eqn. 6)

Where,

c - Components
s - Suppliers
p - Plant
r - Retailer
d – Distribution center
a,b,c - Variables
TSP - Cost of transportation of component from supplier to plant per unit
TPD - Cost of transportation of component from plant to distribution centre
CS – Cost of making a component by the supplier
M_p – Cost of manufacturing of plant per unit
IC_p – Cost of carrying inventory of plant per unit
$I_{C,P}$ – Inventory of component at plant
$TCD_{d,r}$ – Cost of transportation from distribution centre to retailer zone per unit
ICD – Cost of inventory of distribution centre per unit
ID – Inventory at distribution centre

6 Existing cost details in the industry under consideration

The sample existing costs of the parameters from the industry considered for optimization were given in the following Tables (Tab.1-7).

Tab. 1 The existing cost of transportation of all 3 components from all 3 suppliers to plant 1 per unit

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

Tab. 2 The existing cost of transportation of all 3 components from all 3 suppliers to plant 2 per unit

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

Tab. 3 The 'a' variable – existing values – plant 1

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

Tab. 4 The 'a' variable – existing values – plant 2

	C1	C2	C3
S1	30	100	60
S2	150	130	120
S3	80	30	72

Tab. 5 The PD values – existing values

	D1	D2	D3
P1	15	14	16
P2	13	14	16

Tab. 6 The 'b' variable – existing values

	D1	D2	D3
P1	49	55	35
P2	135	60	55

Tab. 7 The existing cost of transportation from all 3 distribution centre to all 6 retailer zones per unit

	R1	R2	R3	R4	R5	R6
D1	7	9	8	5	6	4
D2	10	8	12	4	11	9
D3	8	6	4	3	2	4

The existing cost of manufacturing of plant 1 & 2 per unit (M_p): M_1 = 1800; M2 = 1760.
The existing cost of carrying inventory of plant 1 & 2 per unit (IC_p): IC_1 = 50; IC_2 = 55.
The existing cost of inventory of distribution centre per unit (ICD): ICD_1 = 70; ICD_2 = 85; ICD_3 = 90
The existing inventory at distribution centre (ID):
ID_1 = 150; ID2 = 180; ID_3 = 165
The existing retailer zone demand:
100, 25, 50, 80, 90, 60
The existing selling price at retailer zone:
2000, 2500, 2750, 3000, 3200, 3500

Similarly, the remaining existing cost values of all the parameters were also taken into account for optimization. The existing cost and profit details of the industry under study are given in Tab. 8.

Tab. 8 Existing cost and profit details

Serial Number	Cost	Existing Cost
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**

7 Constraints involved and parameters considered

The sample maximum – minimum limit values for costs followed in the industry were given in the Tab.s below.

***Tab. 9** The Maximum & Minimum Transportation Cost Limits Of All 3 Components From All 3 Suppliers To Plant1 Per Unit*

	C1		C2		C3	
	Min	Max	Min	Max	Min	Max
S1	6	12	10	20	8	15
S2	10	16	4	10	9	14
S3	7	15	9	15	10	15

Tab. 10 *The maximum & minimum transportation cost limits of all 3 components from all 3 suppliers to plant 2 per unit*

	C1		C2		C3	
	Min	Max	Min	Max	Min	Max
S1	9	15	10	20	10	22
S2	10	15	7	12	4	9
S3	10	20	10	20	9	15

Tab. 11 *The 'a' variable – maximum & minimum transportation cost limit values - plant 1*

	C1		C2		C3	
	Min	Max	Min	Max	Min	Max
S1	80	90	60	75	80	85
S2	18	22	70	75	18	25
S3	20	25	8	15	15	20

Tab. 12 *The 'a' variable – maximum & minimum transportation cost limit values - plant 2*

	C1		C2		C3	
	Min	Max	Min	Max	Min	Max
S1	10	33	90	125	85	100
S2	145	165	120	150	90	100
S3	75	90	125	40	70	78

Tab. 13 *The PD Values – Maximum & Minimum Transportation Cost Limit Values*

	D1		D2		D3	
	Min	Max	Min	Max	Min	Max
P1	12	16	13	17	15	20
P2	10	15	12	16	14	18

Tab. 14 *The 'b' Variable – Maximum & Minimum Transportation Cost Limit Values*

	D1		D2		D3	
	Min	Max	Min	Max	Min	Max
P1	40	55	52	60	30	40
P2	130	140	55	65	50	58

The Maximum & Minimum Manufacturing Cost Limits Of Manufacturing Of Plant 1 & 2 Per Unit (Mp): Max: M1 = 2000; M2 = 2100; Min: $M_1 = 1700$; $M_2 = 1600$

The Maximum & Minimum Manufacturing Cost Limits Of Carrying Inventory Of Plant 1 & 2 Per Unit(IC_p): Max: $IC_1 = 75$; $IC_2 = 65$; Min: $IC_1 = 45$; $IC_2 = 50$.

The Maximum & Minimum Distribution Cost Limits Of Inventory Of Distribution Centre Per Unit (ICD): Max: $ICD_1 = 100$; $ICD_2 = 92$; $ICD_3 = 120$; Min: $ICD_1 = 50$; $ICD_2 = 60$; $ICD_3 = 70$

The Maximum & Minimum Inventory At Distribution Centre (Id):
Max: $ID_1 = 170$; $ID_2 = 210$; $ID_3 = 230$; Min: $ID_1 = 100$; $ID_2 = 150$; $ID_3 = 150$

8 Methodology adopted

The software used is MATLAB and the technique used is Genetic Algorithm. The coding is done using MATLAB software and a sample MATLAB window (main function program for transportation cost) is given in Fig. 3 and MATLAB window (main function program for transportation cost) is given in Fig. 4.

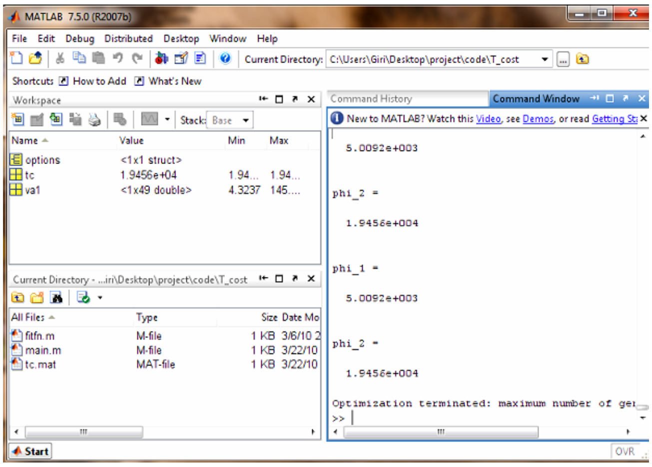

Fig. 3 *Main function window*

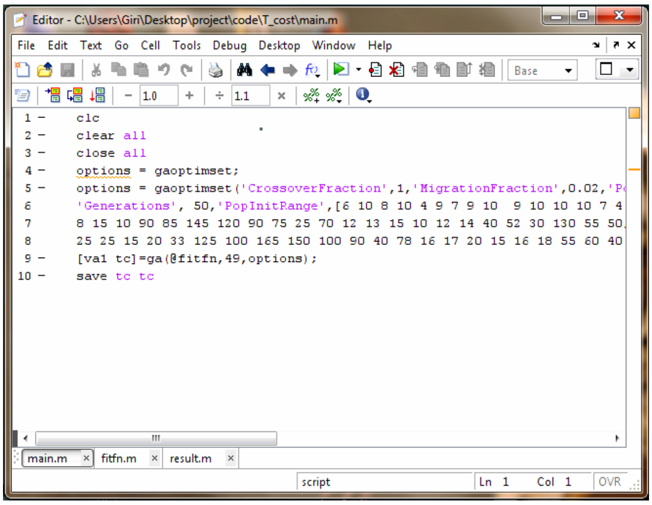

Fig. 4 *Main function program*

8.1 Genetic algorithm codings

The sample coding for the transportation cost using genetic algorithm technique is given below.

Main function for Transporting Cost:

```
clc
clear all
close all
options = gaoptimset;
options =
gaoptimset('CrossoverFraction',1,'MigrationFraction',0.02,'P
opulationSize', 20,...
'Generations', 50,'PopInitRange',[6 10 8 10 4 9 7 9 10  9 10
10 10 7 4 10 10 9 80 60 80 18 70 18 20 ...
8 15 10 90 85 145 120 90 75 25 70 12 13 15 10 12 14 40 52
30 130 55 50;12 20 15 16 10 14 15 15 15 15 20 22 15 12 9
20 20 15 90 75 85 22 75 ...
25 25 15 20 33 125 100 165 150 100 90 40 78 16 17 20 15
16 18 55 60 40 140 65 58],'TimeLimit',
200,'StallTimeLimit',
100,'PlotFcns',{@gaplotbestf,@gaplotbestindiv});
[va1 tc]=ga(@fitfn,49,options);
save tc tc
```

Fitness functions for Transporting Cost:

```
function[phi_2]=fitfn(x)
phi_1=sum
(
Sum
```

(
([x(1) x(2) x(3);x(4) x(5) x(6);x(7) x(8) x(9)].*[x(1) x(2) x(3);x(4) x(5) x(6);x(7) x(8) x(9)])+... (([x(10) x(11) x(12); x(13) x(14)x(15);x(16) x(17) x(18)]).*[x(19) x(20) x(21); x(22) x(23) x(24);x(25) x(26) x(27)])
)
)
phi_2=phi_1+sum(sum(([x(28) x(29) x(30);x(31) x(32) x(33)].*[x(34) x(35) x(36);x(37) x(38) x(39)])))

Similarly, the codings for the other constraints were also incuded for optimization.

9 Results and Discussions

The various costs that are involved in the industry for product manufacturing were optimized. The sample optimum cost values obtained by optimizing through genetic algorithm using MATLAB software is given in the Tab.s 15 – 20.

Tab. 15 The optimized cost of transportation of all 3 components from all 3 suppliers to plant 1 per unit

	C1	C2	C3
S1	8.74	11.99	10.12
S2	12.05	5.63	12.92
S3	9.56	9.16	12.21

Tab. 16 The optimized cost of transportation of all 3 components from all 3 suppliers to plant 2

	C1	C2	C3
S1	9.30	11.20	10.07
S2	12.00	8.86	5.83
S3	17.01	10.53	10.97

Tab. 17 The 'a' variable- optimized values – plant 1

	C1	C2	C3
S1	81.66	62.82	84.93
S2	21.04	73.51	20.62
S3	21.17	8.12	15.35

Tab. 18 The 'a' variable- optimized values – plant 2

	C1	C2	C3
S1	12.60	98.00	85.40
S2	147.72	125.41	90.02
S3	77.25	27.90	70.11

Tab. 19 The PD Values - Optimized Values

	D1	D2	D3
P1	12.06	13.81	15.53
P2	10.97	14.44	17.23

Tab. 20 The 'b' variable – optimized values

	D1	D2	D3
P1	44.60	58.21	31.82
P2	133.97	55.13	55.72

The Optimized Cost of Manufacturing of Plant 1 & 2 Per Unit (Mp): M_1 = 1705.8, M2 = 1604.9
The Optimized Cost of Carrying Inventory of Plant 1 & 2 Per Unit (Ic_p): IC_1 = 47.52, IC_2 = 50.746
The Optimized Cost of Inventory of all 3 Distribution Centers Per Unit (ICD): ICD_1 = 50.054, ICD_2 = 75.491, ICD_3 = 75.274
The Optimized Inventory at Distribution Center (ID): ID_1 = 119.52, ID2 = 156.73, ID_3 = 153.43
The various optimized costs were tabulated in Tab. 21.

Tab. 21 Optimized cost details

Serial Number	Cost	Existing Cost
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

Using Genetic Algorithm (MAT LAB) the optimum values were identified for all the costs. The comparative results of the existing costs and the optimized costs were tabulated in the Tab. 22.

Tab. 22 Comparison of cost details

Serial Number	COST	EXISTING COST RESULT (Rupees)	OPTIMIZED COST RESULT (Rupees)
1.	Transportation cost	19,696	19,552
2.	Supplier cost	2,04,500	1,87,965
3.	Manufacturing cost	7,11,575	6,19,603
4.	Distribution cost	43,683	32,001
5.	**Total operating cost**	**9,79,454**	**8,71,799**
6.	**Profit**	**1,56,946**	**2,66,201**

By optimizing the supply chain network using genetic algorithm 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 organization. The optimized results were also obtained graphically for several iterations and the sample graph(transportation cost) is given in Fig. 5.

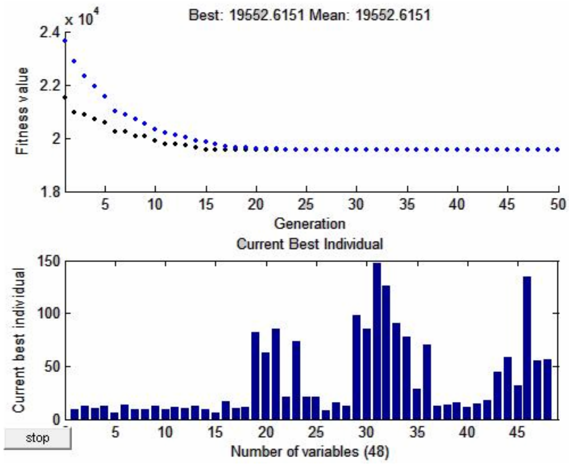

***Fig. 5** Transportation cost graph*

10 Conclusions

In this work, the optimal solution of the job-shop scheduling problem is obtained by using the non-traditional techniques such as genetic algorithm. The major advantage of using these algorithms is that even though the number of possible sequences for 20 operations is very high, an optimal solution is obtained within few minutes while running on a standard PC. 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 approach 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 supply chain network was analyzed and optimized the component and products distribution with optimal total cost of supply chain.

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By substitution of equation (19) to (18), the following value for angle α' is obtained:

$$\cos\alpha' = \frac{\sqrt{2}p_x\sqrt{p_z(1-p_z)} + p_y(1-p_z)}{p_z^2-1}\,. \qquad (20)$$

According to equation (20) the value of $p_z \geq 0$, and the dependencies of (19) and (10) are the solution of the given problem.

In case of the rotary table axis dimensioning against the planes of $O_0x_0y_0z_0$ coordinate system, the following interpretation should be assumed:

- p_x – the sine of the angle between the work piece axis and the $O_0y_0z_0$ plane,
- p_y – the sine of the angle between the work piece axis and the $O_0x_0z_0$ plane,
- p_z – the sine of the angle between the work piece axis and the $O_0x_0y_0$ plane.

3 Conclusions

NC rotary axes connected both with the work piece (rotary tables) and with the tool (spindle heads) significantly facilitate the machining of work pieces with complex planes. Due to the easy combination of the rotary and linear movements the programming of the machining process is significantly simplified.

The presented mathematical dependencies can be used to describe the location of the spindle and work piece axes in any position in spindle heads and rotary tables, either conventional or NC controlled, in both continuous and discrete positioning.

The dependencies thus described may be used by firms manufacturing type Hure double turn spindle heads with discrete positioning by means of Hirth's face toothings.

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