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Optimization Solution to Supply Chain Network Architecture Using New-PSO Algorithm

Rajeshwar S Kadadevaramath*

Department of Industrial Engineering and Management, Siddaganga Institute of Technology, Tumkur, Karnataka, India

Abstract

In today's global competition in manufacturing and distribution, the success of an industry is dependent on cost effective supply chain management under various markets, logistics and production uncertainties. Uncertainties in the supply chain usually decrease profit, i.e. increase total supply chain cost. Optimization is no longer a luxury but has become the order of the day. This paper specifically deals with tactical level model which considers an integrated, multi component, single product, multi stage / multi-echelon and procurement-production-distribution system design problem in a flexible supply chain network configuration. The four stages considered in this research work are vendors, manufacturing plants, warehouses and distribution centers in order of their contributions to the chain. In this work Non-Linear Inertia Weight Particle Swarm Optimization (NLIW-PSO) algorithm has been implemented to optimize of four-echelon supply chain architecture. The Total Supply Chain operating Cost (TSCC) of the supply chain network are considered as a performance indicator.

Keywords: Supply chain; Optimization, Uncertainty; Particle swarm optimization

Introduction

Logistics is often defined as the art of bringing the right amount of right product to the right place at the right time and it usually refers to the supply chain problem The efficiency of the logistics system is influenced by many factors, one of them is to find the location of facilities to be opened and the another important one is to find out the best optimum distribution network strategy such that the customer demand can be satisfied at minimum cost or maximum profit. If the facilities are to distribute directly to the customers, then the single-stage model is appropriate. On the other hand, if several facilities are to be sited between the suppliers to the customers in order to produce or act as regional Distribution Centers (DCs), then the multistage model is the appropriate model. The body of the literature on multistage facility location /allocation problems is large, dealing different models, relevant to various situations [1].

Problem Definition and Mathematical Model

This section briefly describes the objective of the research problem, the model assumptions, the mathematical formulation and the problem description of the four stage multi echelon supply chain network model.

Objective of study

This work specifically deals with tactical level model which considers an integrated, multi component, single product, multi stage/ multi-echelon and procurement-production-distribution system design problem in a flexible supply chain network configuration.

The four stages considered in this research work are vendors, manufacturing plants, warehouses and distribution centers in order of their contributions to the chain. It is to be noted that Non-Linear Inertia Weight Particle Swarm Optimization (NLIW-PSO) algorithm performed well compared with other PSO variants and Genetic algorithm with literature on bench mark problems. It has been proved in the literature that the NLIW-PSO has outperformed the other PSO variants and GA. Therefore, in this work Non-Linear Inertia Weight Particle Swarm Optimization (NLIW-PSO) algorithm has been implemented to optimize of four-echelon supply chain architecture. The Total Supply Chain operating Cost (TSCC) of the supply chain network are considered as a performance indicators [2].

Model assumptions

- Problem is tactical or snap shot pull based problem
- A single product flows through the supply chain network
- A product is made up of three components
- Distribution centers faces random customer demand and demand distribution is assumed to be uniform
- Quantity of goods at every installation takes integer values
- Linear installation holding cost rates exists only for manufacturing plants and distribution centers in the supply chain
- There is no shortage cost (as shortages are not permitted)
- Transportation costs are directly proportional to the quantity shipped
- Manufacturing costs are directly proportional to the quantity of products produced
- There is no lot size discount policy for any installation

All installations have finite capacity

- Problem description

This problem attempts to capture the dynamics of a single product being manufactured out of three different components. There are

***Corresponding author:** Rajeshwar SK, Department of Industrial Engineering and Management, Siddaganga Institute of Technology, Tumkur, Karnataka, India, E-mail: rajeshwarkmath@yahoo.com

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three vendors, two manufacturing plants, three warehouses and six distribution centers as shown in figure 1. In a more general formulation of this problem, the three different components are needed to manufacture a final product and these components can be supplied by any of the three vendors. These components can be shipped to any of the two plants, where the product is made. Then the product made out of them is being shipped to warehouses and then to distribution centers based on the demand [3].

The mathematical formulation of four stage multi echelon supply chain architecture

This sub section develops a mathematical model to quantify the relationship among all the decision variables involved in supply chain network and supply chain decisions in terms of Total Supply Chain operating Cost (TSCC) for SCS-I as the performance indicators. The problem of optimizing the supply chain configuration can be summarized in the following mathematical model. The notations used in the formulation of mathematical model are shown below [3-5].

The first objective function, the Total Supply Chain operating Cost (TSCC), consists of four parts the first part, Total Supplier Cost of Material (TSMC) comprises of total cost of raw materials from all the vendors to plants. The second part, Total Transportation Cost (TTC) is the total transportation cost incurred from all vendors to plants and plant transportation cost to the warehouses. The third part consists of Total Manufacturing Cost incurred at the plants (TMC) and the fourth component, the Total Warehouse Cost (TWC) consists of warehouse inventory carrying cost and the shipping cost of finished goods from warehouse to the respective distribution centers to meet the demand.

Supply chain cost components:

a) Total Supplier Materials Cost

b) Total Transportation Cost

c) Total Manufacturing cost

d) Total Warehouse Cost

e) Total Supply Chain operating Cost

f) Profit of SCN

g) Revenue generated by SCN

Objective functions:

Objective Function 1: Minimize TSCC = TSMC + TTC + TMC + TWC

Subject to following supply chain constraints;

a) Vendor capacity constraint

b) Plant capacity constraint

c) Distribution Center Capacity Constraint:

d) Demand Constraint

All the decision variables should be integers and non negative.

Constraint Handling: Popular constraint handling strategy 'Penalty parameter approach' is used to solve the four echelon supply chain network problem.

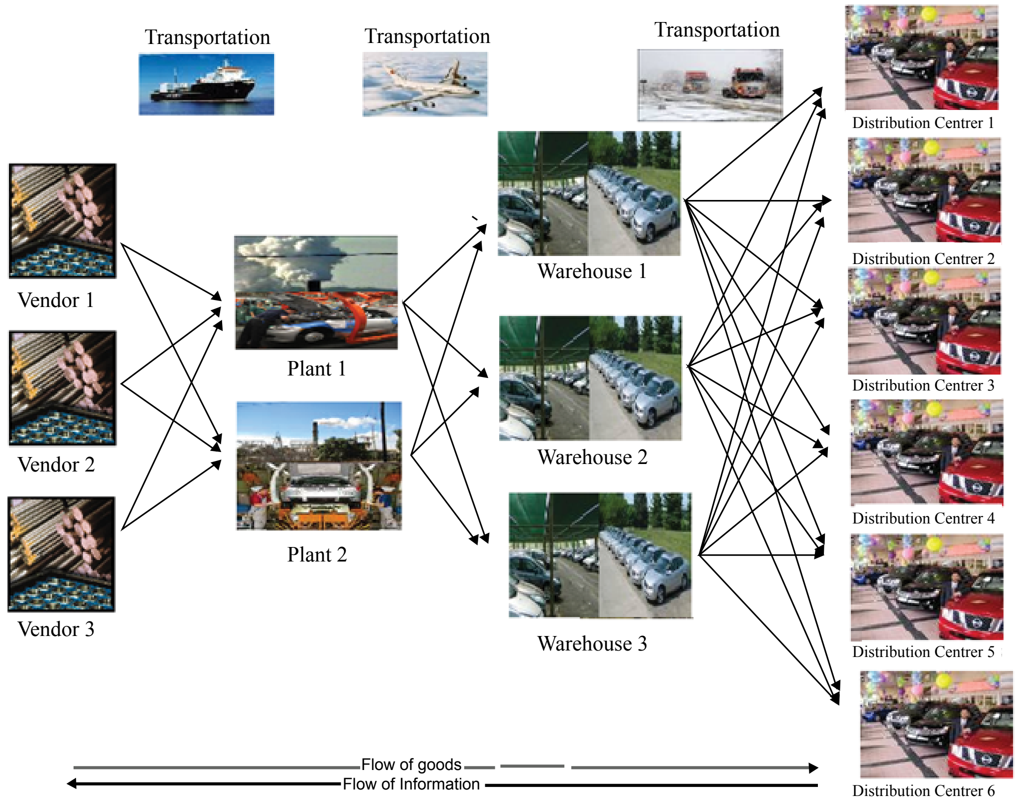

Figure 1: Four echelon supply chain network architecture.

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Optimization of Four Stage Multi-Echelon Supply Chain Network Architecture Using Nliw-Pso Algorithm

Velocity calculation and position updating equations used for optimization of four echelons SCN architecture

The NLIW-PSO variant used in this research study has been briefly explained in the literature. Following are the equations of NLIW-PSO used for velocity calculation and position updating of particles of PSO.

Velocity,

$$v_{kd}^{new} = w_{iter} \times v_{kd} + c_1 \times \left[r_1 \times \left(P_{kd} - X_{kd}\right) \right] + c_2 \times \left[r_2 \times \left(G_d - X_{kd}\right) \right]$$

$$w_{iter} = \left\{ \frac{(iter_{max} - iter)^n}{(iter_{max})^n} \right\} (w_{initial} - w_{final}) + w_{final}$$

$$m = \frac{(w_{initial} - w_{final})}{iter_{max}}$$

$$w_{final} = w_{initial} + m \times iter_{max}$$

$$X_{kd}^{new} = X_{kd} + v_{kd}^{new}$$

Performance Analysis of Four Echelon Supply Chain Network Architecture Using Nliw-Pso Varient

Experimental design

To evaluate the performance measure, the two supply chain settings are considered in this computational study. PSO algorithms were used to optimize the SCS-I with an objective of minimizing total supply chain cost of the supply chain network. We have considered ten demand scenarios for each Supply chain settings. These supply chain test settings consists of different raw material costs, capacities, transportation costs, inventory holding cost, distribution costs and selling prices. Different supply chain settings are used to check the robustness of the proposed algorithms in terms of their consistent and good performance across supply chain network.

Summary

The NLIW-PSO algorithm was proposed recently by called Non linear inertia weight dynamically updating of particle velocity is used because it outperformed all the previous algorithm proposed by researchers in solving bench mark problems considered in the literature and also an extensive performance analysis is carried out on three stage multi echelon SCN network in the previous chapter by all PSO variants and found that NLIW-PSO algorithm out performed in both the supply chain settings [6].

As literature shows that very few attempts have been made to solve complex and multi echelon supply chain network problems. Hence, the present work in this chapter considered the mathematical modeling of four echelon supply chain network and application of the best NLIW-PSO variant of Particle Swarm Optimization algorithm for the best alignment of procurement, production and distribution in four stage multi echelon supply chain network in order to optimize TSCC as first objective and profit as second objective for different supply chain settings of multi echelon supply chain network architecture.

A four stage multi echelon supply chain model was considered and modeled with few assumptions. The model was mathematically represented considering the capacity, inventory balancing and demand constraints at various stages of the supply chain. The constrained mathematical model was solved using NLIW-PSO and with exterior penalty method approach to handle the constraints. A performance analysis of the above algorithm under study was carried out.

Performance analysis of above application of proposed algorithm have been carried out on four stage multi echelon Supply chain Network problem for SCS-I. The algorithm, showed remarkable outcome of performance analysis in minimizing total supply chain operating cost as objective function. The better performance of the above solution methodology is due to the novel solution construction procedure implemented in the algorithm. It is found that this algorithm gives superior results in terms of speed of convergence and the ability of finding the solutions for supply chain of excellent quality. Hence it is believed that this method will be easy and efficient and robust to solve this any kind of complex multi stage multi echelon logistics supply chain architecture design problems.

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