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MODELING OF SUPPLY CHAIN DYNAMICS: A LINGO BASED THREE-TIER DISTRIBUTION APPROACH

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Abstract

The term supply chain is defined as an integrated process wherein a number of various business entities (i.e., suppliers, manufacturers, distributors, and retailers) work together in an effort to: (1) acquire raw materials, (2) convert these raw materials into specified final products, and (3) deliver these final products to retailers. This chain is traditionally characterized by a forward flow of materials and a backward flow of information. At its highest level, a supply chain is comprised of two basic, integrated processes: (1) the Production Planning and Inventory Control Process, and (2) the Distribution and Logistics Process.

A global economy and increase in customer expectations in terms of cost and services have put a premium on effective supply chain reengineering. It is essential to perform risk-benefit analysis of reengineering alternatives before making a final decision. Simulation [Towill and Del Vecchio (1994)] provides an effective pragmatic approach to detailed analysis and evaluation of supply chain design and management alternatives. However, the utility of this methodology is hampered by the time and effort required to develop models with sufficient fidelity to the actual supply chain of interest. In this paper, we describe a supply chain LINGO based modeling framework designed to overcome this difficulty.

In modeling of supply chain, the variables [decision) are chosen in such a manner to optimize one or more measures [Lee and Whang (1993) and Chen (1997)] can be represent as functions of one or more decision variables performance measures. The decision variables generally used in supply chain modeling are Inventory Levels, and Number of Stages (Echelons): in supply chain, the number of stages is called echelons. This involves either increasing or decreasing the chain's level of vertical integration by combining (or eradicating) stages or separating (or adding) echelons respectively. On the analytical point of view. In this research model, we minimize shipping costs over a three tiered (Echelon) distribution system consisting of plants, distribution centers, and customers. Plants produce multiple products that are shipped to distribution centers. If a distribution center is used, it incurs a fixed cost. Customers are supplied by a single distribution center.

Key Words: Supply chain management system (SCMS), echelons, supply chain sourcing, sc design; dynamic optimization, Simulation.

1. Introduction:

The term supply chain is defined as an integrated process in which a number of different business entities (i.e., suppliers, manufacturers, distributors, and retailers etc.) work together in an effort to: (1) acquire raw materials, (2) convert these raw materials into specified final products, and (3) deliver these final products to retailers. This chain is traditionally characterized by a forward flow of materials and a backward flow of information (Lee & Billington, 1993).

In recent years enterprises have been looking for effective methods to control their costs and make fast and correct decisions in a pressured, competitive, and rapidly changing market environment. Supply Chain Management (SCM) which enables businesses to design and optimize the whole process of **their** multi-echelon SC.

The supply chain management is concerned with the flow of products and information between the supply chain members that encompasses all of those organizations such as suppliers, producers, service providers and customers (Figure 1). These organizations linked together to acquire, purchase, convert/manufacture, assemble, and distribute goods and services, from suppliers to the ultimate and users.

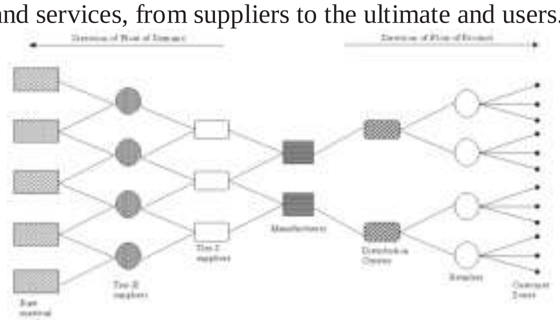


Fig.-1: Supply Chain Network

1.1 Inter Organizational Information System:

In supply chain management, the suppliers, producers, retailers, customers, and service providers are the members and are linked through the ultimate level of integration. These members are continuously supplied with information in real time. The foundation of the ability to share information is the effective use of Information Technology within the supply chain. Appropriate application of these technologies provides decision makers with timely access to all required information from any location within the supply chain. Recognizing the critical importance of information in an integrated supply chain environment, many organizations are implementing some form of an inter-organizational information system (IOIS). IOISs are the systems based on information technologies that cross organization boundaries.

1.2 The Supply Chain Information Process:

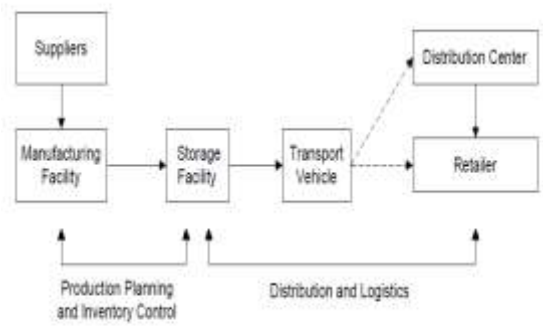


Fig.-2

The Process of Production Planning and Inventory Control encompasses the manufacturing and storage sub-processes, and their interface(s). More specifically, production planning describes the design and management of the entire manufacturing process (including raw material scheduling and acquisition, manufacturing process design and scheduling, and material handling design and control). Inventory control describes the design and management of the storage policies and procedures for raw materials, work-in-process inventories, and usually, final products.

The Distribution and Logistics Process determines how products are retrieved and transported from the warehouse to retailers. These products may be transported to retailers directly, or may first be moved to distribution facilities, which, in turn, transport products to retailers. This process includes the management of inventory retrieval, transportation, and final product delivery. These processes interact with one another to produce an integrated supply chain. The design and management of these processes determine the extent to which the supply chain works as a unit to meet required performance objectives.

Considering the importance and the influence of supply chain management (SCM), manufacturers and retailers like the IBM and Wal-Mart have paid great efforts to handle the flow of products efficiently and coordinate the management of supply chain smoothly. Typically, supply chain decisions can be categorized into three sets based on the horizons of their effects (Shi *et al.* 2004), i.e., strategic, tactical, and operational decisions. The strategic decisions focus on the long-term effects on a company and consider the global economic environments, e.g. supply chain network configuration, strategic supplier selection, etc. The tactical level decisions include selecting specific locations among all the potential ones, searching for the optimal allocation and transportation policies in the supply chain network. The tactical decisions are made once a year or more. The operational level decisions, such as scheduling, are usually made on a daily basis to handle the detailed operations of a company.

Design of a supply chain involves determination of i) the number and location of supply chain facilities, including plants, distribution centers, warehouses and depots, ii) the transportation links and modes between facilities, and iii) the policies to operate a supply chain, such as inventory control policy, carrier loading policy etc. The first two types of decisions are often strategic decisions, while the determination of policies are more at the tactical and/or operational level. These decisions are often mixed together in the real business cases.

2. Supply Chain Network Optimization:

2.1. Supply Chain Optimization

An important component in supply chain design is determining how an effective supply chain design is achieved, given a set of decision variables [Lee and Whang (1993) and Chen (1997)] Chen (1997) seeks to develop optimal inventory decision rules for managers that result in the minimum long-run average holding and backorder costs for the entire system.

Since majority of the models use inventory level as a decision variable and cost as a performance measure in Supply Chain Optimization. The supply chain network design problem have been studied in the academia for a long time. Geoffrion and Powers (1995) analyzed the evolution of distribution system design in the past twenty years before 1995. A number of elements are identified which have significantly contributed to the evolution of distribution systems, including the logistics functionalities, information systems, developed algorithms and enterprise management systems. They also claimed that customer service and client requests will remain as the most fundamental aspects for research. For supply chain optimization practitioners, one major obstacle is related to supply chain uncertainties and dynamics. The stochastic nature of supply chains makes most analytical models either over simplistic or computationally intractable.

2.2. Review of Optimization & Supply Chain Model:

Generally, multi-stage models for supply chain design and analysis can be divided into four categories: 1) deterministic analytical models, in which the variables are known and specified, 2) stochastic analytical models, where at least one of the variables is unknown, and is assumed to follow a particular probability distribution, 3) economic models, and 4) simulation models.

Deterministic Analytical Models

Williams (1981) presents seven heuristic algorithms for scheduling production and distribution operations in an assembly supply chain network (i.e., each station has at most one immediate successor, but any number of immediate predecessors). The objective of each heuristic is to determine a minimum-cost production and/or product distribution schedule that satisfies final product demand. Finally, the performance of each heuristic is compared using a wide range of empirical experiments, and recommendations are made on the bases of solution quality and network structure. Williams (1983) develops a dynamic programming algorithm for simultaneously determining the production and distribution batch sizes at each node within a supply chain network. Ishii, et. al (1988) develop a deterministic model for determining the base stock levels and lead times associated with the lowest cost solution for an integrated supply chain on a finite horizon.

Cohen and Lee (1989) present a deterministic, mixed integer, non-linear mathematical programming model, based on economic order quantity (EOQ) techniques, More specifically, the objective function used in their model maximizes the total after-tax profit for the manufacturing facilities and distribution centers (total revenue less total before-tax costs less taxes due). This objective function is subject to a number of constraints, including managerial constraints. (resource and production constraints) and logical consistency constraints. (feasibility, availability, demand limits, and variable non-negativity).

Cohen and Moon (1990) extend Cohen and Lee (1989) by developing a constrained optimization model, called PILOT, to investigate the effects of various parameters on supply chain cost, and consider the additional problem of determining which manufacturing facilities and distribution centers should be open. More specifically, the authors consider a supply chain consisting of raw material suppliers, manufacturing facilities, distribution centers, and retailers. This system produces final products and intermediate products, using various types of raw materials.

Newhart, et. al. (1993) design an optimal supply chain using a two-phase approach. The first phase is a combination mathematical program and heuristic model, with the objective of minimizing the number of distinct product types held in inventory throughout the supply chain. The second phase is a spreadsheet-based inventory model, which determines the minimum amount of safety stock required to absorb demand and lead time fluctuations.

Arntzen, et. al. (1995) develop a mixed integer programming model, called GSCM (Global Supply Chain Model), that can accommodate multiple products, facilities, stages (echelons), time periods, and transportation modes. Voudouris (1996) develops a mathematical model designed to improve efficiency and responsiveness in a supply chain. The model maximizes system flexibility, as measured by the time-based sum of instantaneous differences between the capacities and utilizations inventory resources and activity resources. Camm, et. al. (1997) develop an integer programming model, based on an un-capacitated facility location formulation, for Procter and Gamble Company. The purpose of the model is to: (1) determine the location of distribution centers (DCs) and (2) assign those selected DCs to customer zones.

Stochastic Analytical Models

Cohen and Lee (1988) develop a model for establishing a material requirements policy for all materials for every stage in the supply chain production system. The authors use four different cost-based sub-models: Material Control, Production Control, Finished Goods Stockpile (Warehouse) and Distribution.

Svoronos and Zipkin (1991) consider multi-echelon, distribution-type supply chain systems (i.e., each facility has at most one direct predecessor, but any number of direct successors). Lee and Billington (1993) develop a heuristic stochastic model for managing material flows on a site-by-site basis. The authors propose an approach to operational and delivery processes that consider differences in target market structures (e.g., differences in language, environment, or governments). The objective of the research is to design the product and production processes that are suitable for different market segments that result in the lowest cost and highest customer service levels overall. Pyke and Cohen (1993) develop a mathematical programming model for an integrated supply chain, using stochastic sub-models to calculate the values of the included random variables with mathematical program. The authors consider a three-level supply chain, consisting of one product, one manufacturing facility, one warehousing facility, and one retailer. The model minimizes total cost, subject to a service level constraint, and holds the set-up times, processing times, and replenishment lead times constant. In Pyke and Cohen (1994), the authors again consider an integrated supply chain with one manufacturing facility, one warehouse, and one retailer, but now consider multiple product types. The new model yields similar outputs; however, it determines the key decision variables for each product type. More specifically, this model yields the approximate economic (minimum cost) reorder interval (for each product type), replenishment batch sizes (for each product type), and the order up-to product levels (for the retailer, for each product type) for a particular supply chain network. Tzafestas and Kapsiotis (1994) utilize a deterministic mathematical programming approach to optimize a supply chain, then use simulation techniques to analyze a numerical example of their optimization model.

Economic Models

Christy and Grout (1994) develop an economic, game-theoretic framework for modeling the buyer-supplier relationship in a supply chain. The basis of this work is a 2 x 2 supply chain relationship matrix., which may be used to identify conditions under which each type of relationship is desired. These conditions range from high to low *process* specificity, and from high to low *product* specificity.

Simulation Models

The terms “modelling” and “simulation” are often used interchangeably” (DoD, 1998). Many efforts for modelling and simulating SC systems have been made since the 1950's. Santa-Eulalia et al. *SC Simulation*: represents descriptive modelling techniques, in which the main objective is to create models for describing the system itself. Modeler's develop these kinds of models to understand the modelled system and/or to compare the performance of different systems. Several techniques were surveyed, including System Dynamics (Kim & Oh, 2005), Monte Carlo Simulation (Bower, Griffith & Cooney, 2005), Discrete-Event Simulation (Van Der Vorst, Tromp, & Van der Zee, 2005), Combined Discrete-Continuous techniques (Lee & Liu, 2002) and Supply Chain Games (Van Horne & Marier, 2005). Towill (1991) and Towill, et. al. (1992) use simulation techniques to evaluate the effects of various supply chain strategies on demand amplification. The strategies investigated are as follows:

(1) Eliminating the distribution echelon of the supply chain, by including the distribution function in the manufacturing echelon.
(2) Integrating the flow of information throughout the chain.
(3) Implementing a Just-In-Time (JIT) inventory policy to reduce time delays.
(4) Improving the movement of intermediate products and materials by modifying the order quantity procedures.
(5) Modifying the parameters of the existing order quantity procedures.

The objective of the simulation model is to determine which strategies are the most effective in smoothing the variations in the demand pattern. Wikner, et. al. (1991) examine five supply chain improvement strategies, and then implement these strategies on a three-stage reference supply chain model.

Solvers Used Internally by LINGO

LINGO is a simple tool for utilizing the power of linear and nonlinear optimization to formulate large problems concisely, solve them, and analyze the solution. Optimization helps to find the answer that yields the best result; attains the highest profit, output, or happiness; or achieves the lowest cost, waste, or discomfort. Often these problems involve making the most efficient use of resources—including money, time, machinery, staff, inventory, and more.

LINGO has four solvers it uses to solve different types of models. These solvers are:

- a direct solver,
- a linear solver,
- a nonlinear solver, and
- a branch-and-bound manager.

The LINGO solvers, unlike solvers sold with other modeling languages, are all part of the same program. In other words, they are linked directly to the modeling language. This allows LINGO to pass data to its solvers directly through memory, rather than through intermediate files. Direct links to LINGO's solvers also minimize compatibility problems between the modeling language component and the solver components.

When you solve a model, the direct solver first computes the values for as many variables as possible. If the direct solver finds an equality constraint with only one unknown variable, it determines a value for the variable that satisfies the constraint. The direct solver stops when it runs out of unknown variables or there are no longer any equality constraints with a single remaining unknown variable.

Once the direct solver is finished, if all variables have been computed, LINGO displays the solution report. If unknown variables remain, LINGO determines what solvers to use on a model by examining its structure and mathematical content. For a continuous linear model, LINGO calls the linear solver. If the model contains one or more nonlinear constraints, LINGO calls the nonlinear solver. When the model contains any integer restrictions, the branch-and-bound manager is invoked to enforce them. The branch-and-bound manager will, in turn, call either the linear or nonlinear solver depending upon the nature of the model.

The linear solver in LINGO uses the revised simplex method with product form inverse. A barrier solver may also be obtained, as an option, for solving linear models. LINGO's nonlinear solver employs both successive linear programming (SLP) and generalized reduced gradient (GRG) algorithms. Integer models are solved using the branch-and-bound method. On linear integer models, LINGO does considerable preprocessing, adding constraint "cuts" to restrict the noninteger feasible region. These cuts will greatly improve solution times for most integer programming models.

3. Research Optimization Model:

LINGO Based Supply Chain – Three Tier Distribution Model:

In this model, we minimize shipping costs over a three tiered distribution system consisting of plants, distribution centers, and customers. Plants produce multiple products that are shipped to distribution centers. If a distribution center is used, it incurs a fixed cost. Customers are supplied by a single distribution center.

This is a three tier (3 stages) shipping/supply chain system. It consists of plants at one level, distribution centers are on second level and customers are on the third level. There are three plants P1, P2 and P3. each plant produced two types of products say A, B; which supplied to 4 distribution centers DC1, DC2, DC3, DC4. Each Distribution centre has fixed cost F. On the third tier system, there are five customers say C1, C2, C3, C4 and C5 and the demand for each customer is denoted by D. S indicate the capacity for a product at a plant, but the condition is that each customer Ci (i = 1,2, …..5) is served by one distribution centre which is indicated by Y. X = Quantity to be supplied in tons, and C = Cost/tone of a product from plant to a distribution centre and G = Cost/ton of a product from a distribution centre to a customer.

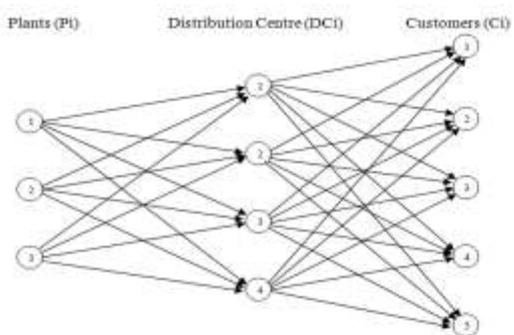


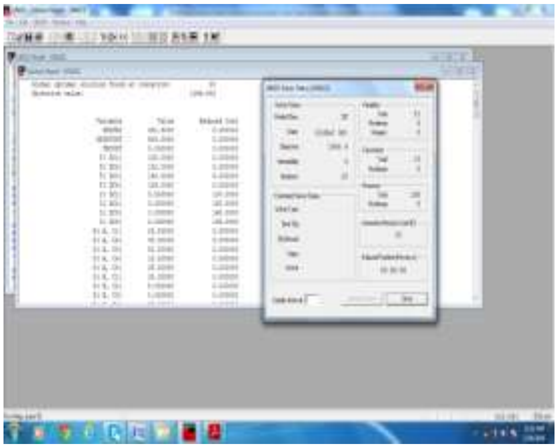
Figure-3: Multi Level Decision Model Distribution System

LINGO Programme of the Research Model:

```
SETS:
! Two products;
PRODUCT/ A, B/;
! Three plants;
PLANT/ P1, P2, P3/;
! Each DC has an associated fixed cost, F,
and an "open" indicator, Z.;
DISTCTR/ DC1, DC2, DC3, DC4/: F, Z;
! Five customers;
CUSTOMER/ C1, C2, C3, C4, C5/;
! D = Demand for a product by a customer.;
DEMLINK(PRODUCT, CUSTOMER): D;
! S = Capacity for a product at a plant.;
SUPLINK(PRODUCT, PLANT): S;
! Each customer is served by one DC,
indicated by Y.;
YLINK(DISTCTR, CUSTOMER): Y;
! C= Cost/ton of a product from a plant to a DC,
X= tons shipped.;
CLINK(PRODUCT, PLANT, DISTCTR): C, X;
! G= Cost/ton of a product from a DC to a customer.;
GLINK(PRODUCT, DISTCTR, CUSTOMER): G;
ENDSETS
DATA:
! Plant Capacities;
S = 80, 40, 75,
20, 60, 75;
! Shipping costs, plant to DC;
C = 1, 3, 3, 5, ! Product A;
4, 4.5, 1.5, 3.8,
2, 3.3, 2.2, 3.2,
1, 2, 2, 5, ! Product B;
4, 4.6, 1.3, 3.5,
1.8, 3, 2, 3.5;
! DC fixed costs;
F = 100, 150, 160, 139;
! Shipping costs, DC to customer;
G = 5, 5, 3, 2, 4, ! Product A;
5.1, 4.9, 3.3, 2.5, 2.7,
3.5, 2, 1.9, 4, 4.3,
1, 1.8, 4.9, 4.8, 2,
5, 4.9, 3.3, 2.5, 4.1, ! Product B;
5, 4.8, 3, 2.2, 2.5,
3.2, 2, 1.7, 3.5, 4,
1.5, 2, 5, 5, 2.3;
! Customer Demands;
D = 25, 30, 50, 15, 35,
25, 8, 0, 30, 30;
ENDDATA
!——————————————————————————
——;
! Objective function minimizes costs.;
[OBJ] MIN = SHIPDC + SHIPCUST + FXCOST;
SHIPDC = @SUM(CLINK: C * X);
SHIPCUST =
@SUM(GLINK(I, K, L):
G(I, K, L) * D(I, L) * Y(K, L));
FXCOST = @SUM(DISTCTR: F * Z);
! Supply Constraints;
@FOR(PRODUCT(I):
@FOR(PLANT(J):
@SUM(DISTCTR(K): X(I, J, K)) <= S(I, J))
);
! DC balance constraints;
@FOR(PRODUCT(I):
@FOR(DISTCTR(K):
@SUM(PLANT(J): X(I, J, K)) =
@SUM(CUSTOMER(L): D(I, L)* Y(K, L))
);
! Demand;
```

@FOR(CUSTOMER(L):
@SUM(DISTCTR(K): Y(K, L)) = 1);

3.1. LINGO Programme Output:



Screen print for optimal solution by LINGO

The *solver status* window is useful for monitoring the progress of the solver and the dimensions of the model. The *Variables* box shows the total number of variables in the model. The *Variables* box also displays the number of the total variables that are *nonlinear*. It also gives you a count of the total number of *integer* variables in the model. In general, the more nonlinear and integer variables your model has, the more difficult it will be to solve to optimality in a reasonable amount of time. The *Constraints* box shows the total constraints in the model and the number of these constraints that are *nonlinear*. The *Non-zeros* box shows the total *non-zero coefficients* in the model.

The *Slack or Surplus* column in a LINGO solution report tells you how close you are to satisfying a constraint as an equality. Dual prices are sometimes called *shadow prices*, interpret the amount that the objective would improve as the right-hand side, or constant term, of the constraint is increased by one unit.

Global optimal solution found at iteration: 20
Objective value: 1066.400

Variable	Value	Reduced Cost
SHIPDC	431.9000	0.000000
SHIPCUST	634.5000	0.000000
FXCOST	0.000000	0.000000
F(DC1)	100.0000	0.000000
F(DC2)	150.0000	0.000000
F(DC3)	160.0000	0.000000
F(DC4)	139.0000	0.000000
Z(DC1)	0.000000	100.0000
Z(DC2)	0.000000	150.0000
Z(DC3)	0.000000	160.0000
Z(DC4)	0.000000	139.0000
D(A, C1)	25.00000	0.000000
D(A, C2)	30.00000	0.000000
D(A, C3)	50.00000	0.000000
D(A, C4)	15.00000	0.000000
D(A, C5)	35.00000	0.000000
D(B, C1)	25.00000	0.000000
D(B, C2)	8.000000	0.000000
D(B, C3)	0.000000	0.000000
D(B, C4)	30.00000	0.000000
D(B, C5)	30.00000	0.000000
S(A, P1)	80.00000	0.000000
S(A, P2)	40.00000	0.000000
S(A, P3)	75.00000	0.000000
S(B, P1)	20.00000	0.000000
S(B, P2)	60.00000	0.000000
S(B, P3)	75.00000	0.000000
Y(DC1, C1)	0.000000	92.50000
Y(DC1, C2)	0.000000	84.20000
Y(DC1, C3)	0.6000000	0.000000
Y(DC1, C4)	1.000000	0.000000
Y(DC1, C5)	1.000000	0.000000
Y(DC2, C1)	0.000000	170.0000
Y(DC2, C2)	0.000000	148.4000
Y(DC2, C3)	0.000000	115.0000
Y(DC2, C4)	0.000000	58.50000
Y(DC2, C5)	0.000000	6.500000
Y(DC3, C1)	0.000000	25.00000
Y(DC3, C2)	1.000000	0.000000
Y(DC3, C3)	0.4000000	0.000000
Y(DC3, C4)	0.000000	61.50000
Y(DC3, C5)	0.000000	31.00000

```
                 Y( DC4, C1)        1.000000
0.000000
                 Y( DC4, C2)        0.000000
41.60000
                 Y( DC4, C3)        0.000000
200.0000
                 Y( DC4, C4)        0.000000
199.5000
                 Y( DC4, C5)        0.000000
0.5000000
              C( A, P1, DC1)        1.000000
0.000000
              C( A, P1, DC2)        3.000000
0.000000
              C( A, P1, DC3)        3.000000
0.000000
              C( A, P1, DC4)        5.000000
0.000000
              C( A, P2, DC1)        4.000000
0.000000
              C( A, P2, DC2)        4.500000
0.000000
              C( A, P2, DC3)        1.500000
0.000000
              C( A, P2, DC4)        3.800000
0.000000
              C( A, P3, DC1)        2.000000
0.000000
              C( A, P3, DC2)        3.300000
0.000000
              C( A, P3, DC3)        2.200000
0.000000
              C( A, P3, DC4)        3.200000
0.000000
              C( B, P1, DC1)        1.000000
0.000000
              C( B, P1, DC2)        2.000000
0.000000
              C( B, P1, DC3)        2.000000
0.000000
              C( B, P1, DC4)        5.000000
0.000000
              C( B, P2, DC1)        4.000000
0.000000
              C( B, P2, DC2)        4.600000
0.000000
              C( B, P2, DC3)        1.300000
0.000000
              C( B, P2, DC4)        3.500000
0.000000
              C( B, P3, DC1)        1.800000
0.000000
              C( B, P3, DC2)        3.000000
0.000000
              C( B, P3, DC3)        2.000000
0.000000
              C( B, P3, DC4)        3.500000
0.000000
              X( A, P1, DC1)        80.00000
0.000000
              X( A, P1, DC2)        0.000000
0.000000
              X( A, P1, DC3)        0.000000
0.9000000
              X( A, P1, DC4)        0.000000
1.900000
              X( A, P2, DC1)        0.000000
3.600000
              X( A, P2, DC2)        0.000000
2.100000
              X( A, P2, DC3)        40.00000
0.000000
              X( A, P2, DC4)        0.000000
1.300000
              X( A, P3, DC1)        0.000000
0.9000000
              X( A, P3, DC2)        0.000000
0.2000000

              X( A, P3, DC3)        10.00000
0.000000
              X( A, P3, DC4)        25.00000
0.000000
              X( B, P1, DC1)        20.00000
0.000000
              X( B, P1, DC2)        0.000000
0.000000
              X( B, P1, DC3)        0.000000
1.500000
              X( B, P1, DC4)        0.000000
2.300000
              X( B, P2, DC1)        0.000000
2.200000
              X( B, P2, DC2)        0.000000
1.800000
              X( B, P2, DC3)        8.000000
0.000000
              X( B, P2, DC4)        0.000000
0.000000
              X( B, P3, DC1)        40.00000
0.000000
              X( B, P3, DC2)        0.000000
0.2000000
              X( B, P3, DC3)        0.000000
0.7000000
              X( B, P3, DC4)        25.00000
0.000000
              G( A, DC1, C1)        5.000000
0.000000
              G( A, DC1, C2)        5.000000
0.000000
              G( A, DC1, C3)        3.000000
0.000000
              G( A, DC1, C4)        2.000000
0.000000
              G( A, DC1, C5)        4.000000
0.000000
              G( A, DC2, C1)        5.100000
0.000000
              G( A, DC2, C2)        4.900000
0.000000
              G( A, DC2, C3)        3.300000
0.000000
              G( A, DC2, C4)        2.500000
0.000000
              G( A, DC2, C5)        2.700000
0.000000
              G( A, DC3, C1)        3.500000
0.000000
              G( A, DC3, C2)        2.000000
0.000000
              G( A, DC3, C3)        1.900000
0.000000
              G( A, DC3, C4)        4.000000
0.000000
              G( A, DC3, C5)        4.300000
0.000000
              G( A, DC4, C1)        1.000000
0.000000
              G( A, DC4, C2)        1.800000
0.000000
              G( A, DC4, C3)        4.900000
0.000000
              G( A, DC4, C4)        4.800000
0.000000
              G( A, DC4, C5)        2.000000
0.000000
              G( B, DC1, C1)        5.000000
0.000000
              G( B, DC1, C2)        4.900000
0.000000
              G( B, DC1, C3)        3.300000
0.000000
              G( B, DC1, C4)        2.500000
0.000000
              G( B, DC1, C5)        4.100000
0.000000
```

```
                 G( B, DC2, C1)        5.000000
0.000000
                 G( B, DC2, C2)        4.800000
0.000000
                 G( B, DC2, C3)        3.000000
0.000000
                 G( B, DC2, C4)        2.200000
0.000000
                 G( B, DC2, C5)        2.500000
0.000000
                 G( B, DC3, C1)        3.200000
0.000000
                 G( B, DC3, C2)        2.000000
0.000000
                 G( B, DC3, C3)        1.700000
0.000000
                 G( B, DC3, C4)        3.500000
0.000000
                 G( B, DC3, C5)        4.000000
0.000000
                 G( B, DC4, C1)        1.500000
0.000000
                 G( B, DC4, C2)        2.000000
0.000000
                 G( B, DC4, C3)        5.000000
0.000000
                 G( B, DC4, C4)        5.000000
0.000000
                 G( B, DC4, C5)        2.300000
0.000000

                            Row      Slack or Surplus
Dual Price
                            OBJ        1066.400
-1.000000
                              2        0.000000
-1.000000
                              3        0.000000
-1.000000
                              4        0.000000
-1.000000
                              5        0.000000
0.1000000
                              6        0.000000
0.7000000
                              7        40.00000
0.000000
                              8        0.000000
0.8000000
                              9        52.00000
0.000000
                             10        10.00000
0.000000
                             11        0.000000
-1.100000
                             12        0.000000
-3.100000
                             13        0.000000
-2.200000
                             14        0.000000
-3.200000
                             15        0.000000
-1.800000
                             16        0.000000
-2.800000
                             17        0.000000
-1.300000
                             18        0.000000
-3.500000
                             19        0.000000
-230.0000
                             20        0.000000
-152.4000
                             21        0.000000
-205.0000
                             22        0.000000
-175.5000
                             23        0.000000
-355.5000
```

4. Conclusion:

Not every optimization procedure is suitable for all Supply Chain models and it is necessary to choose the appropriate procedure depending on the features of the SC. This paper gives an overview of the software tool LINGO in Supply-chain Network Optimization. Practice demonstrates that the combination of Lingo based optimization and Supply chain could help decision makers gain many insights from a real supply chain and finally improve its efficiency and effectiveness. The limitations of traditional approaches to solving the problem of dynamic global optimization of the SCN are based on their inability to work with incomplete information, complex dynamic interactions between the elements, or the need for centralization of control and information. Most of the heuristic techniques on the other hand, do not guarantee the overall system optimization. In this paper, the problem of Supply Chain Dynamics for Three Tier Distribution System is addressed within the framework of optimization theory based on Lingo software. This model is useful in many for online decision making in dynamic systems such as job shop scheduling, material handling, electrical power dispatching as well as management of robot end effectors in hybrid systems. The model can be generalized for the large multi-complex problem if the system supports to run the programme. There are many hidden parameters in heuristic method while in the LINGO based model, no need to add any such variables and the solution becomes easier and applicable.

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