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DESIGN OF A MULTI-ECHELON GLOBAL SUPPLY CHAIN NETWORK WITH MICROSOFTå¨ EXCEL PREMIUM SOLVER PLATAFORM

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MICROSOFT® EXCEL PREMIUM SOLVER PLATAFORM

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Accepted by:
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ABSTRACT

I designed a global supply chain distribution model of one single product, with the objective of minimizing the costs of transportation, handling materials, duties and tariffs, production, and fixed infrastructure. The distribution network has a combination of manufacturing facilities (fixed and to-be-determined), warehouses (to-be-determined), distribution centers (to-be-determined), and customer zones at fixed locations. This network design is similar to the mathematical mixed-integer linear model from Tsiakis, Shah and Pantelides (2001). This model has been implemented in Microsoft Excel, using the Standard Simplex method from Frontline, Inc. This model optimizes the number of facilities worldwide (multi-echelon) along with the flow of materials per transportation node to meet demand of several regions of the world. Any combination of nodes is possible, although the production rate at each manufacturing facility must be able to provide all materials required at each region - no extension is allowed. A supplementary mixed-integer model is provided to address country's economic freedom when selecting global manufacturing sites.

DEDICATION

I dedicate this work to my son Rick, my two daughters Natalia and Mariana, and to my wife Eliete. I also dedicate this work to my Dad and my Mom, who still live in Goiânia, Brazil.

ACKNOWLDGEMENTS

I would like to thank my advisor, Dr. Mary Beth Kurz, for all of her assistance and guidance. I am also grateful to the other committee members: Dr. William Ferrell and Dr. Maria E. Mayorga. I would like to thank Dr. Hills and Dr. Hammig for their support over my tenure at the Department of Applied Economics and Statistics, Clemson University.

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INTRODUCTION

It is believed that international trade is the precursor of prosperity (Wolf, 2004). According to Milton Friedman (1995), democratization of information has played a major role for the world to achieve the level of trade that it currently holds today along with lower costs of transportation and communication. Thus, multi-national companies must focus on network designs that take advantage of global business integration in order to reduce costs and increase their comparative advantages.

Cohen and Mallik (1997) argue that greater competition and consumer values have created the need for multi-national companies to adopt new competitive strategy. However, decisions made at the strategic level require a comprehensive knowledge of all levels (points) of the companies' supply chain. For the design of strategic decisions for a global supply chain, companies should consider the following factors (Smits, 2001):

- o Number and location of warehouses and distribution centers.

- o Amount of inventory to hold at each point.

- o Holding or handling capacity at each point.

- o Possible transportation modes between points.

By adding the flow of materials between echelons to the list of factors, companies' managers can improve supply chain performance at the tactical level as well. Because tactical decisions also include lead times and service levels, most network distribution models do not consider inventory management as part of the problem to be optimized. For this reason, the

global supply chain model that I have designed does not consider all the tactical decisions to be made, except for the flow of materials.

In terms of model implementation, Kellogg Company has been known as the leading firm in implementing a linear program to optimize global operational and tactical decisions. They have used spreadsheets along with special software for materials requirements planning (MRP) to optimize operational decisions such as weekly production, inventory and distribution (Brown, Keegan, Vigus, and Wood, 2001, p. 2). However, the model turned out to be excellent for tactical decisions such as capacity expansions and capacity reassignments. The model is still under development to address current global trade issues.

Decisions to open and close facilities must be made by corporate management. For a mathematical model to duplicate reality, it is necessary that decisions be accepted and implemented through model re-optimization based on management judgments. No model is all-inclusive without human interaction. Shapiro and others (1993) see the utilization of mixed-integer programming very appropriate for distribution network problems because "it extends the resource-allocation capabilities of linear programming to capture nonlinear costs and resource allocations and to allow nonnumeric conditions to be imposed on a strategy." For this reason, I selected a mixed-integer model that includes fixed costs for operating the warehouses, distribution centers and manufacturing plants.

It stands to reason that producing items close to local markets is desirable. However, it is important to take into account the fixed costs of operating all these plants, warehouses and distributions centers. Because multi-national logistics networks depend on several different factors including political stability, trade barriers, local content rules, general infrastructure, monetary exchange rates, tariffs, duties, export taxes, and transfer prices, it is

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much more difficult to quantify the objective of the mathematical model (Schmidt and Wilhelm, 1999, p. 3). As a result, I added some of these factors to the selected mixed-integer model so as to help quantify and predict some of these country-dependent values.

There are several successful examples of companies that fully embraced global supply chain models to redesign their manufacturing and distribution strategy. For instance, the Compaq Computer Company has modified its product design and global logistics network in order to improve, expedite the customization of PCs. The model came up with modular assemblies at a few plants (e.g. Texas, Scotland, Brazil, Singapore and China) to be customized (final assembly) at the distribution centers (Schmidt and Wilhelm, 1999, p. 3). The Digital Equipment Corporation has designed one of the most successful large mixed-integer linear programs to design new product pipelines, reduce the vendor base, and restructure the distribution network and manufacturing sites. The model came with a reduction of manufacturing plants from 33 to 12 and has saved over $500 million dollars (Arntzen, Brown, Harrison, and Trafton, 1995, p. 81-84). Apple Computers, Hewlett-Packard (HP), Xerox Corporation, Ford Company, and General Motors also have made use of global supply chain optimization models to restructure their worldwide manufacturing and distribution networks.

So far, global supply chain modeling has shown great potential for multi-national firms to maximize profits and minimize costs. However, there is some criticism about the lack of complexity in these models in regards to price and demand uncertainties in international markets (Cohen and Mallik, 1997, p. 207). For this research work, I have not taken into account these two levels of uncertainty because the selected mixed-integer model assumes deterministic demand and I arranged for a fixed transfer price to be determined.

Because governments create all sorts of regulations to hinder international market integration for fear of "denationalization," the Economic Freedom Index from The Heritage Foundation adequately accounts for the autonomy and privileges given to multi-national companies to manufacture and distribute goods and services. In other words, market uncertainty can be measured by individuals' lack of freedom to work, produce, consume, and invest in any way they please (Kane, Holmes and O'Grady, 2006, p. 38). As a result, this measure of "uncertainty" will be incorporated into the mixed-integer program for subsequent selection of manufacturing plants, warehouses and distribution centers.

DISTRIBUTION OF ECONOMIC FREEDOM

Fig. 1 – Distribution of Economic Freedom (http://www.heritage.org/research/features/index/)
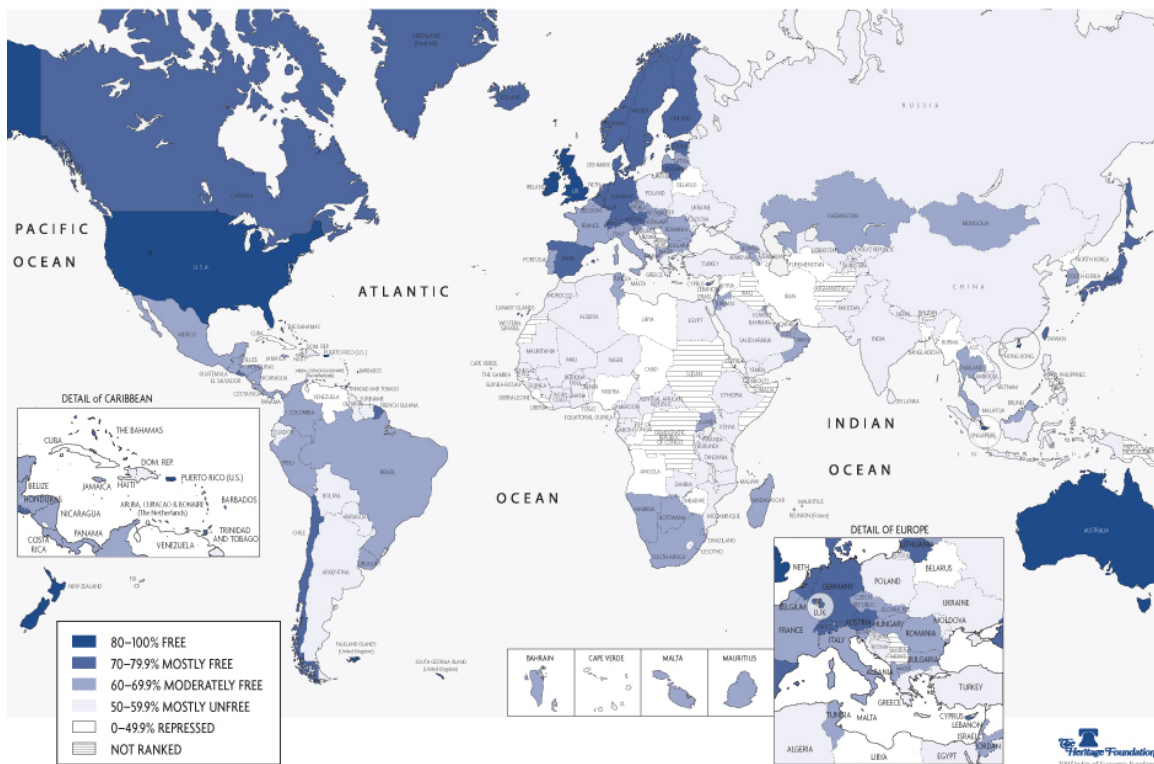
The objective of my thesis is to implement a strategic planning model using Microsoft Excel Solver (Premium Simplex) for the selection of worldwide manufacturing

sites, distribution sites, transportation nodes and flow of products between nodes. The mixed-integer model will select manufacturing sites and then will assume these selected sites fixed for a subsequent re-optimization. Also, a supplemental mixed-integer model will help select all related sites by means of the Economic Freedom Index. Sensitivity analysis will be presented subsequently.

This work is challenging for a variety of reasons. It assumes that products can be shipped to all countries in the world. The model has the following features: deterministic in nature, single product, three stages of the supply chain, single period, linear production and transportation costs, and cost minimization. The customer zones are pre-defined regions of the world with deterministic demand. Any shipment is allowed from plants to warehouses, from warehouses to distribution centers, and from distribution centers to customer zones. Excel is to be used as a computer application for global supply chain optimization, including charts, data tables and pivot charts. The inclusion of an economic freedom index as a coefficient for decision variable selection has never been tested before.

The work is to be done by means of a few major tasks:

1. Develop a mixed-integer model formulation for global supply chain strategic planning in Excel assuming potential manufacturing sites, warehouse facilities and distribution centers.

2. Modify the mixed-integer model to assume selected, optimal manufacturing sites as fixed locations for the global supply chain strategic planning.

3. Determine and analyze the optimal solution strategy to gain an understanding of the movement of goods across the five continents.

4. Redefine the mixed-integer model formulation to account for uncertainties in countries' economic freedom assuming potential manufacturing sites, warehouse facilities and distribution centers.

5. Analyze the results and compare with the original model (1).

6. Perform sensitivity analysis to improve supply chain strategic gains when using single source suppliers.

CHAPTER 1 - LITERATURE REVIEW

Cohen (1997) depicts two distinct approaches in terms of literature on global supply chain management strategy planning: network flow models and option valuation models. The first approach has to do with production-distribution network and includes the location of plants, warehouses and distributions centers as well as the flow of materials among these facilities to meet customer demand in designated market areas. The second approach has to do with the swap in production or sourcing sites based on continuing changes in certain events such as exchange rate, market conditions, political situation, and competition environment. The global supply chain model designed for this work relates to the first approach so I will cover the literature on network flow models only. According to Aikens (1995) and Goetschalckx (1997), mathematical models on production-distribution networks should be classified this way (Smits, 2001, p. 3-11):

1. Production-distribution (plants to-be-determined) or distribution (plants are given) models.

2. Objectives: minimization of costs or maximization of profits.

3. Number of Echelons: none (plant to customer), one (plant to warehouse to customer), two (plant to warehouse to distribution center to customer), or three (plant to second tier warehouse to first tier warehouse to distribution center to customer).

4. Demand pattern: deterministic, stochastic or dynamic.

5. Multi-product or single product model.

6. Uncapacitated warehouses (no limit on capacity), uniformly capacitated warehouses (maximum capacity the same for all warehouses) or different capacitated warehouses (maximum capacity not the same for all warehouses).

7. No single sourced customer-product (any warehouse delivers), single sourced customers (only one warehouse delivers to customer), single source product (only one warehouse delivers a product to all customers), or single sourced customer-product (only one warehouse delivers a product to a customer).

8. Customer service requirement: no requirement (no performance is measured), customer demand satisfaction (order delivered at the right place, at the right time and at the right quantity), maximum time and distance (lead time constraints), and customer service level (percentage of orders satisfied from stock).

9. Transportation costs: fixed distribution costs (cost per unit to ship from location to another), linear distribution costs (based on the number of units transported or piecewise linear function), or probability distribution costs (based on the utilization degree of the flows of goods).

10. Facility costs: no costs, fixed costs to operate the facility, piece-wise linear production costs (economies of scale on production throughput), or piece-wise linear inventory costs (based on the maximum inventory level).

11. Inventory management (using single echelon or multi-echelon, along with safety stocks and/or lead time): no inventory control included, inventory control with deterministic demand, dynamic demand, or stochastic demand.

12. Material handling: no handling costs, physical handling costs (based on average throughput), or clerical handling costs (based on the number of products shipped).

13. International features: no costs or transaction costs, related to taxes, duties, transfer prices, exchange rates and trade barriers.

14. Lead times (transportation time, handling time and waiting time because of stockouts): not included, deterministic lead times or stochastic lead times (approximations).

15. Pipeline inventory: no costs included or costs for holding inventory in the pipeline (trucks, trains, boats, or physical pipeline)

Most distribution network literatures have neither echelon inventory management costs nor pipeline inventory costs and lead times in their mathematical models. Thus, inventory management must not be a matter of concern for this literature review since the model to be implemented in later chapters does not take inventory costs into account. The most important aspect of global supply chain modeling is to be able to analyze the costs and benefits of the feasible strategy choices given by the optimal solutions. Very complex models do not capture the managerial needs because approximations are used indistinctly and therefore difficult to optimize. However, there are a few production-distribution network models that offer some insights and therefore must be examined in this chapter.

The model of Kuehn and Hambuger (1963) is a zero-echelon model, therefore no warehouses, with the objective of allocating customers to manufacturing facilities. Their cost minimization distribution model includes deterministic demand, fixed transportation costs, uncapacitated warehouse, single product and fixed facility costs. Efroymson and Ray (1966), Spielberg (1969), Khumawala (1972) and Khumawala and Whybark (1976) models followed the footsteps of the abovementioned model. Respectively, the first model made use of the branch and bound approach to find the plant locations as its decision variables, the second

model utilized side constraints to capture feasible plant locations and the third and fourth models employed another branch and bound algorithm for the warehouse location problem. In terms of warehouse capacity, Erlenkotter (1978) also created a model that included a dual-based procedure for uncapacitated facility location.

Elson (1972) has developed a mixed-programming model using side location constraints for finding out the optimal warehouse locations. In his model, he made use of one echelon for the distribution of multiple stock items and was on of the first modelers to include linear transportation costs per transported unit and multiple products.

Akinc, and Khumawala (1977) developed a fast and user friendly algorithm for a capacitated warehouse location problem. In his distribution model, he made use of a number of warehouses that received a particular product from manufacturing plants and delivered it to customers. His cost minimization distribution model also includes deterministic demand, fixed transportation costs, single product and fixed facility costs. Nauss (1978) has created a similar model, but he has improved the algorithm to solve the problem faster. Dearing and Newruck (1979) have also created a similar capacitated warehouse location problem, but in his model he assessed the size of each warehouse as to become a bottleneck.

Warszawski (1973) followed the previous multi-product model from Elson (1972) and developed a model to solve a cost minimization multi-dimentional location problem with dynamic demand. Khumawala and Neebe (1978) evaluated the abovementioned model and developed a multiple product, one-echelon location problem with the use of deterministic demand as opposed to dynamic demand. Years later, Neebe and Khumawala (1981) improved the algorithm for the multi-commodity location problem previously developed in 1978 to have capacity for more links between echelons. Karkazis and Boffey

(1981) have also created their cost minimization multi-dimentional distribution model to contain deterministic demand, fixed transportation costs, uncapacitated warehouse, and fixed facility costs.

Production-distribution models abound in the optimization literature. In a distribution network model, the locations of factories are previously established, whereas the locations of factories are to be defined in a production-distribution network through the use of costs of productions as well as the size and distance to first-tier and second-tier warehouses. Now, it is time to review some of the production-distribution profit maximization/cost minimization models for their influence on the design of global supply chain models.

Geoffrion and Graves (1974) were one of the first to include capacitated facilities in a multi-commodity production distribution model. They made use of an approach named Bender decomposition to solve the mixed-integer location problem, including transportation and investment cost. In their model, they had all plants produce finished goods and then ship the finished goods to distribution centers, which in turn ship the goods to customer zones, taking into account supply chain constraints and demand constraints. They took into account the location and capacity of each distribution center. The model assumes capacitated warehouse along with single sourced distribution to a particular customer zone. In other words, only one distribution center is allocated to ship products to a customer zone. No international feature is proposed in the model.

Cohen and Lee (1989) developed a mixed-integer linear programming model that sought to maximize the global supply chain after-tax profit for running a number of plants and distribution centers. It is a one echelon, single-period, multi-commodity, and

deterministic demand model with uncapacitated facilities that includes the assignment of vendors to manufacturing plants to distribution centers to customer zones. It also resulted in the optimal product mix for each plant taking into account some international features such as exchange rate, taxes, tariffs and transfer prices. Their model was one of the first models to address some global supply chain elements. Hodder and Jucker (1982, 1985) had done equivalent work in plant location for multinational firms.

In Cohen and Moon (1991), economies of scale is introduced by means of using a concave piece-wise linear function for the production costs. It is a one echelon, single-period, multi-commodity, and deterministic demand production-distribution model using uncapacitated facilities with the objective of minimizing the costs of production and distribution when selecting international sites for manufacturing plants and distributions centers. Their optimization model, named PILOT, takes into account the same international features of the abovementioned model.

International logistic network considerations have been mentioned briefly so far. In the global business arena, supply chain coordination, difference in taxes along with duty drawbacks, tariffs, fluctuating exchange rates and transfer prices play an important role in defining the number and location of facilities necessary to meet global demand. Because the main objective of this work is to identify the flow of materials among the to-be-defined international facilities, it is now time to review a few more models that deal with global supply chain features. Some of the following models have been used to support the global supply chain strategy in their respective business applications:

o The decision support system, PLANETS, has been designed to support the multinational plant location strategy at General Motors. It is a mixed-integer

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programming model that takes into account international political conditions, financial components of international business, global manufacturing costs (duties, taxes, tariffs), global distribution costs and planning horizon. Breitman and Lucas (1987) have never presented the model formulation in journals or proceedings.

o A mixed-integer programming model has been designed by Xerox Corporation to redesign its global manufacturing operations. Cohen and Mallik (1997) reported that the model described by Barons is a global sourcing model that tries to minimize the total cost of the entire life of a product. For the model to be solved, it is necessary to select the possible international sites and their transaction costs, transportation modes and inventory levels, multinational standard compliance, etc.

o Another mixed-integer programming model from Kouvelis and Rosenblatt (1997) has been designed to address an optimal design of a global logistics network. In their model, they take into account some countries' policies to attract foreign direct investment by using all sorts of financial advantages such as lower taxes, low interest financing and local content regulations.

o Arntzen et al. (1995) have developed one of the most relevant models in the history of global supply chain optimization. Their Global Supply Chain Model (GSCM) has the objective to minimize a weighted combination of total operating costs (including production, inventory, transportation and fixed costs) and activity days. The reported results were said to optimize the number of warehouses, the location of the warehouses, the flows of materials among

facilities, the number of echelons, the flow of materials to customer zones, the manufacturing technology at each facility, and the product mix at each manufacturing plant.

- o MacCormack et al. (1994) created a four-phased heuristic model to identify global site locations based on: core competencies of the multinational firm; market access, technology and risk effect of each site; infrastructure of each site; and a mathematical model.

- o Kogut (1985) has been one of the first to solve problems of global supply chain coordination. In his work, general coordination in terms of facility location, inventory management, production planning and distribution is qualitatively addressed based on comparative advantage of countries and distribution effectiveness of the firm.

There are many other decent models out there that focus on solving the same distribution network problems. These models do not offer global supply chain features, but they can be adjusted to account for those international location costs and benefits. Several of these models will be presented until the end of this chapter. Two of these models are described by Camm et al. (1997). Their successful mixed-integer and linear programming model were implemented at the Procter and Gamble Company and were used during the company's restructuring process to determine the location of distribution centers and the assignment of links from distribution centers to customer zones. The first was an uncapacitated warehouse location problem whereas the second was a transportation assignment model.

Jolayemi and Olorunniwo (2004) developed a deterministic integrated production-planning mixed-integer model for planning production and quantities to be transported in a multi-plant and multi-warehouse environment with extensible capacities. The objective of this model is to maximize total profit by determining the optimal product mix per manufacturing facility, the optimal quantities to be transported from plants to warehouses to customers, the optimal number of warehouses and the optimal capacity of each facility. The model accounts for subcontracting when full manufacturing capacity is achieved and is not able to meet demand. Also, the model assesses the required capacity extension at each warehouse to fully satisfy demand in the future.

Pirkul and Jayarama (1996) reported that they developed a tri-echelon (vendor-plant-warehouse-customer) multi-product mixed-integer programming model, with Lagrangian relaxation, to select manufacturing plants, their assignments to warehouses and the assignment of warehouses to customers. They also developed another mixed-integer model, the PLANWAR model, which has similar objectives to the previous model, but it offers selected manufacturing and warehouse sites as well as a group of potential customers.

Arntzen et al. (1995), followed by Goetschalckx et al. (1995), created a model that takes into account handling costs associated with physical handling of materials that are to be produced and/or distributed. In his model, Smits (2001) made use of staff handling cost which has to do with all activities performed by administrative personnel in handling all paperwork and activities to make materials flow throughout the supply chain.

Finally, Tsiakis et al. (2001) created a mixed-integer linear programming model that tries to optimize the infrastructure and operating costs of a two-echelon supply chain network. In their model, each customer is assigned to one individual distribution center and

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each distribution center is assigned to one single warehouse, only. The manufacturing facilities were first set in fixed locations, whereas warehouses (first echelon) and distributions centers (second echelon) were to be selected by a number of pre-selected sites. This model neither takes into account any international feature nor considers multi-plant multi-warehouse coordination. In figure 2, the map of each continent is shown without the potential sites for manufacturing, warehouses and distribution centers. The decisions about these sites will be described later in chapters 2 and 3.
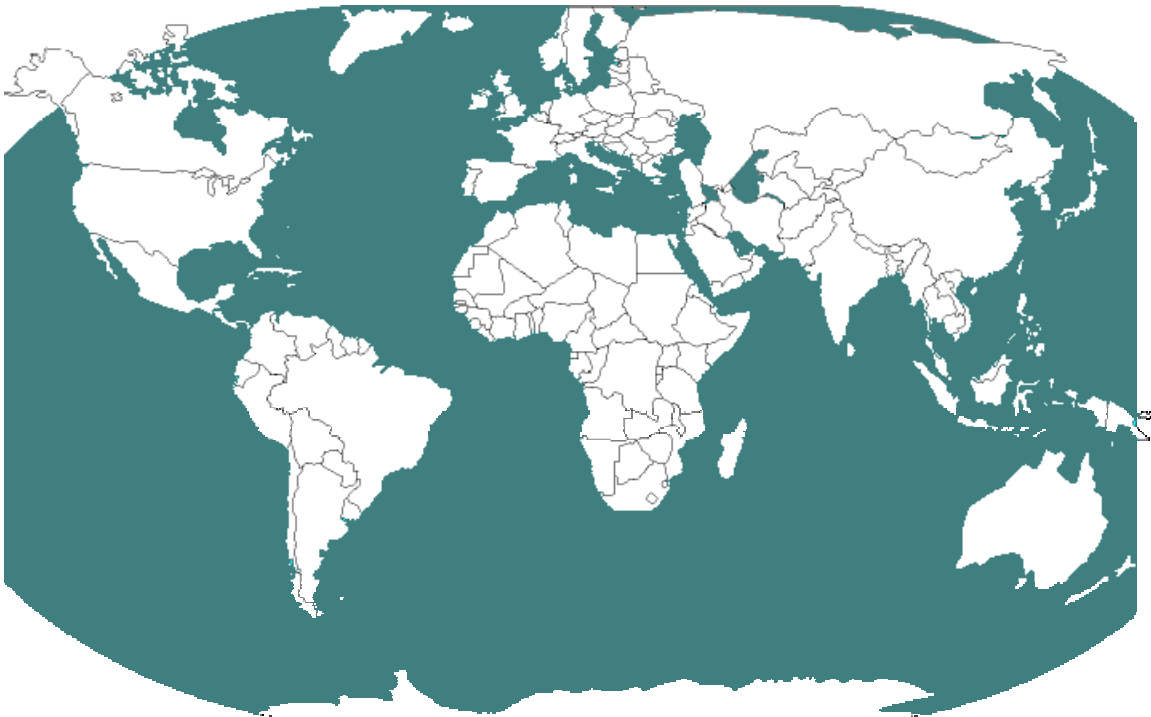
Fig. 2 – World Map without Sites for the Distribution Network

From the examination of relevant literature on distribution and production-distribution networks, it is evident now that there are enough optimization models that have successfully addressed the strategic needs of multinational companies. Other models, not

presented in this work, also account for multiple time periods and uncertainties in demand

and in exchange rates. However, I listed all the deterministic models that are significantly for

me to apply the concept of global supply chain modeling using Microsoft® Excel.

CHAPTER 2 - THE GLOBAL SUPPLY CHAIN MODEL

The global production-distribution (supply chain) network model that has been implemented in Microsoft® Excel for the completion of this master's degree includes the location of plants, warehouses and distributions centers as well as the flow of materials among these facilities to meet customer demand in designated market areas. This model is similar to the model created by Tsiakis and Pantelides (2001) who focused on the minimization of the total annualized cost of the network, taking into consideration both infrastructure and operating costs. Their model includes decisions related to the number, location, and capacity of warehouses and distributions centers to be established, the transportation nodes that are necessary to move materials from between echelons, and the flow and production rates of materials.

An overview of a typical supply chain was given by Tsiakis and Pantelides in the following form:

- Suppliers of raw materials are the key initiators of the supply chain trough frequent deliveries of materials that go straight to production of final goods. The global supply chain model (GSCM) developed in Microsoft® Excel does not include this stage as a parameter for cost minimization.

- Manufacturing sites determine the quantity to be produced at each location based on forecasted demand at the customer level and the production capacity. Each plant has a distinct production cost that accounts for the direct and indirect costs of transforming inputs into outputs. Also, the cost differences among these global facilities are directly related to labor cost, labor productivity, production

technology, costs of raw materials including transportation costs, payroll taxes, local taxes and regulatory fees.

- Products move along the pipeline to the final destination (customer) trough several other echelons that have the objective of facilitating the flow of final goods in a timely manner. Too many warehouses may add complexity to the network in terms of product outflow from plants. Too many distribution centers may also add complexity in terms of product inflow from warehouses. Each link between units is subject to maximum and minimum capacities.

- These two stages of the supply chain, warehouses and distribution centers, are also subject to storage and handling capacities. One warehouse can be supplied by several plants or one single plant. One distribution center can be supplied by several warehouses or one single warehouse. There is a fixed cost to operate theses facilities if they are already in place.

- Customers are the final destination for these products through the distribution centers. The location for these inventories, called echelons, add complexity to the network as orders move from customers to distribution centers, distribution centers to warehouses, and warehouses to plants.

The Microsoft® Excel model allows any distribution center to deliver products to any customer zone. These customer zones are assumed to pertain to a certain market agglomeration with common political and market characteristics. The echelons (plants, warehouses, and distribution centers) to be selected are assumed to be integrated through information systems and processing delays are not considered an important factor. If facility

locations are to be selected, then there is an annualized investment cost to be considered in the model. This model has the potential to address improvement issues in both production planning, and distribution and logistics processes. Each site has capacity constraints and handling costs to account for the operations efficiency. Below is an illustration of this abovementioned supply chain network.
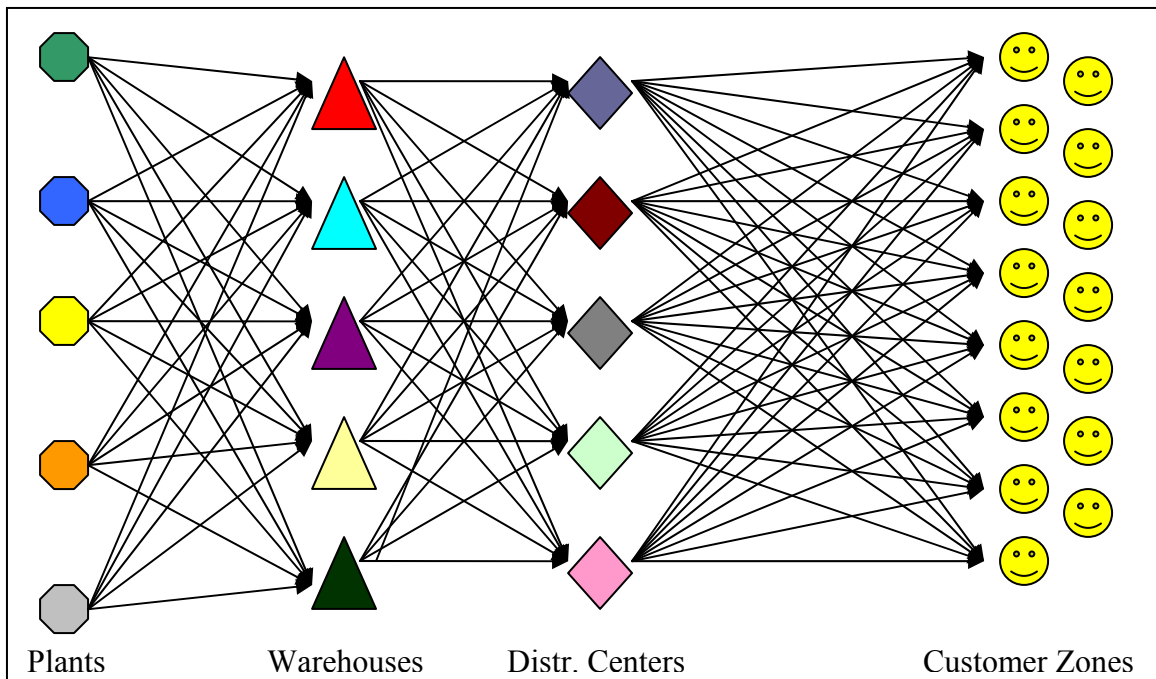
Fig. 3 – The Supply Chain Production-Distribution Network.

The objective of major supply chains is to minimize the costs of operating these facilities or the investment in new facilities if they do not exist, the production costs of a few selected plants, the lead time to deliver the products between echelons, transportation costs, and inventory holding costs. Tsiakis and Pantelides described their model to be involved in strategic and operational decisions, such as:

- Location decisions: number, size, and physical location of all plants, warehouses, and distribution centers.

- Production decisions: the products to be produced at each plant and the allocation of the suppliers to plants, of plants to distribution centers, and of distribution centers to customers.

- Inventory decisions: the level of inventory and management.

- Transportation decisions: the size of each shipment of material and the transportation media to be utilized.

Different from some heuristic-based approaches for scheduling production and distribution operations in supply chain networks, comparing them with this deterministic demand approach, this Microsoft® Excel model assumes that delivery lags between facilities are possible along with:

1. Plants, warehouses and distribution centers to-be-determined or to-be-maintained.

2. Different capacitated warehouses (maximum capacity not the same for all warehouses).

3. No single sourced customer-product (any warehouse delivers).

4. Transportation costs: fixed distribution costs (cost per unit to ship from location to another.

5. Facility costs: fixed costs to operate the facility.

6. Inventory management: no inventory control included.

7. Material handling: clerical handling costs (based on the number of products shipped).

8. International features: transaction costs, related to duties and tariffs, and transfer prices.

9. Lead times (transportation time, handling time and waiting time): deterministic lead times. Delayed differentiation is not included in the model.

10. Pipeline inventory: no costs for holding inventory in the pipeline (trucks, trains, boats, or physical pipeline).

11. Network of multiple facilities (echelons) are not mutually exclusive. A single location can be centralized for a plant, a warehouse and a distribution center.

All in all, this model has the objective to minimize the total distribution cost, including transportation, material handling, transactions, and annualized investment. This lowest cost solution also takes into account the customer demand per geographic zones, capacity constraints of each echelon and the freedom index of doing business in each global market. Since this is a single product model, it determines where each product should be produced, how much should be produced in each plant, and from each plant products should be shipped to warehouses to distribution centers to customer zones. As a Mixed-Integer Linear Program (MILP), it is solved using branch-and-bound techniques. Compared to the model of Tsiakis and Pantelides, this global supply chain model has less complexity since it does not solve for multiple products, economies of scale in transportation and uncertainty in the product demands. However, it is acceptable for dealing with commodities (single product) where the volume transported is already scaled for large shipping and product demand forecasting is highly standardized by governmental organizations.

The manufacturing sites, warehouses and distribution centers can be thought of as fixed locations or to be selected from a set of candidate locations. As fixed locations, they incur a fixed infrastructure cost to keep them operating. As to-be-selected locations, the investment cost is what should matter for the optimal solution. Material handling costs are

incurred independent of the network structure related to warehouses and distribution centers (fixed or to-be-selected). Each warehouse can be supplied by more than one manufacturing site. Each distribution center can be supplied by more than one warehouse. Both warehouses and distribution centers are constrained by minimum and maximum product handling capacity. The objective is the minimization of the total annualized cost of the distribution network in terms of facility infrastructure cost, handling cost, freedom index, transportation cost, tariffs and lead time.

The **binary variables** that are made necessary to the selection of the manufacturing facilities (p), warehouses (w) and distribution centers (d) are shown below:

$$Y_p = \begin{cases} 1, & \textit{if the plant at candidate location p is to be established} \\ 0, & \textit{otherwise} \end{cases}$$

$$Y_w = \begin{cases} 1, & \textit{if the warehouse at candidate location w is to be established} \\ 0, & \textit{otherwise} \end{cases}$$

$$Y_d = \begin{cases} 1, & \textit{if the distribution center at candidate location d is to be established} \\ 0, & \textit{otherwise} \end{cases}$$

The **binary variables** that are made necessary to the selection of the transportation links between facilities and to customer zones (z) are shown below:

$$X_{pw} = \begin{cases} 1, & \textit{if plant p is to ship to warehouse w} \\ 0, & \textit{otherwise} \end{cases}$$

$$X_{wd} = \begin{cases} 1, & \textit{if warehouse w is to ship to distribution center d} \\ 0, & \textit{otherwise} \end{cases}$$

$$X_{dz} = \begin{cases} 1, & \textit{if distribution center d is to ship to customer zone z} \\ 0, & \textit{otherwise} \end{cases}$$

Some **continuous variables** (parameters) are necessary to be included in the model to be optimized depending on production cost (C_p) in each plant in dollars, the production capacity at plants (P_p^{max} and P_p^{min}) in units, the handling capacity in units at the warehouses (W_w^{max} and W_w^{min}), the handling capacity in units at the distribution centers (DC_d^{max} and DC_d^{min}), the fixed-infrastructure cost or investment in dollars at each plant (I_p), at each warehouse (I_w), and at each distribution center (I_d), the transportation costs between facilities (C_{pw}, C_{wd}, and C_{dz}) in dollars, the transportation link capacity between facilities (L_{pw}^{max}, L_{wd}^{max}, and L_{dz}^{max}) in units, the material handling costs in dollars at each warehouse (H_w), the material handling costs at each distribution center (H_d) in dollars, the tariffs and duties incurred by the warehouses (T_w), the tariffs and duties incurred by the distribution centers (T_d), the transfer price of each plant (TP_p), the transfer price of each warehouse (TP_w), the transportation link lead time in hours between facilties (LT_{pw}, LT_{wd}, and LT_{dz}), the distance in miles between facilties (DT_{pw}, DT_{wd}, and DT_{dz}), conversion factor to tons in the transfer price (TON) and product demand at each geographic zone (D_z). Therefore, here is the list of the **decision variables**:

Q_p = rate of production by plant p.

Q_{pw} = rate of flow of the product from plant p to warehouse w.

Q_{wd} = rate of flow of the product from warehouse w to distribution center d.

Q_{dz} = rate of flow of the product from distribution center d to customer zone z.

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Before presenting the **constraints** of the distribution network, it is necessary to include three more constants to be used in the model to take into account the risk to do business in the hosting countries where facilities should be located: the inverse value (subtracted by 100, since it is a minimization model) of the freedom index of each country represented by plants, warehouses and distribution centers (F_p, F_w, and F_d). There are five distinct groups of constraints that I used for this global supply chain model:

Logical Constraints for Transportation Flows

- A flow of material between a plant p and a warehouse w can take place only if the corresponding connection exists:

$$Q_{pw} \leq L_{pw}^{max} X_{pw} \qquad , \forall \ p, w$$

- A flow of material between a warehouse w and a distribution center d can take place only if the corresponding connection exists:

$$Q_{wd} \leq L_{wd}^{max} X_{wd} \qquad , \forall \ w, d$$

- A flow of material between a distribution center d and a customer zone z can take place only if the corresponding connection exists:

$$Q_{dz} \leq L_{dz}^{max} X_{dz} \qquad , \forall \ d, z$$

Network Structure Constraints

- If a plant does not exist, then a link between a plant p and a warehouse w cannot exist:

$$X_{pw} \leq Y_p \qquad , \forall \ p, w$$

- It stands to reason that if a warehouse does not exist, a link between a warehouse w and a distribution center d cannot exist either:

$$X_{wd} \leq Y_d \qquad , \forall\ p, w$$

- A link between a warehouse w and a distribution center d can exist only if the warehouse exists:

$$X_{wd} \leq Y_w \qquad , \forall\ w, d$$

- Also, the same link between a warehouse w and a distribution center d can exist only if the distribution center exists:

$$X_{wd} \leq Y_d \qquad , \forall\ w, d$$

- If a distribution center does not exist, then a link between a distribution center d and a customer zone z cannot exist:

$$X_{dz} \leq Y_d \qquad , \forall\ d, z$$

Logical Constraints for facility and plant production capacities

- There is a minimum and maximum production capacity at each manufacturing site. If a plant does exist, then production cannot exceed the maximum production limit or be lower than its minimum maintenance level:

$$Q_p \leq P_p^{max}\ Y_p \qquad , \forall\ p$$

$$Q_p \geq P_p^{min}\ Y_p \qquad , \forall\ p$$

- The capacity of the warehouses also lies between a minimum and maximum limit due to the internal capabilities and space to handle and store materials at each location. If a

warehouse does exist, then flow of materials that they handle cannot exceed the maximum capacity limit or be lower than its minimum operational level:

$$\sum_p Q_{pw} \leq W_w^{max} Y_w \qquad , \forall\ w$$

$$\sum_p Q_{pw} \geq W_w^{min} Y_w \qquad , \forall\ w$$

- The capacity of the distribution centers also lies between a minimum and maximum limit due to same abovementioned reasons. If a distribution center does exist, then flow of materials that they handle cannot exceed the maximum capacity limit or be lower than its minimum operational level:

$$\sum_w Q_{wd} \leq DC_d^{max} Y_d \qquad , \forall\ d$$

$$\sum_w Q_{wd} \geq DC_d^{min} Y_d \qquad , \forall\ d$$

Material Balance Constraints

- There is no stock accumulation or depletion, since this model does not take into account any inventory management or control. Thus, the production rate at plant p must be the same as the total flow of materials from plant p to all warehouses w:

$$Q_p = \sum_w Q_{pw} \qquad , \forall\ p$$

- The total rate of flow leaving a warehouse w must equal the total rate of flow of materials entering all the distribution centers d:

$$\sum_p Q_{pw} = \sum_d Q_{wd} \qquad , \forall\ w$$

- The total rate of flow leaving a distribution center d must equal the total rate of flow of materials entering all the customer zones z:

$$\sum_w Q_{wd} = \sum_z Q_{dz} \quad , \forall\ d$$

- The total rate of flow received by each customer zone z must equal the corresponding market demand:

$$\sum_d Q_{dz} = D_z \quad , \forall\ z$$

Nonnegativity Constraints

All continuous variables must be nonnegative:

$$Q_p \geq 0 \quad , \forall\ p$$

$$Q_{pw} \geq 0 \quad , \forall\ p, w$$

$$Q_{wd} \geq 0 \quad , \forall\ w, d$$

$$Q_{dz} \geq 0 \quad , \forall\ d, z$$

The final step to have this distribution network model ready for optimization is to set up the appropriate **objective function** that takes into account the capital required to operate or establish the facilities, and the operating costs of the network, such as handling, transportation, tariffs, and production costs. Therefore, there are seven distinct groups of sub-objectives that the objective function accounts for:

Fixed Infrastructure Costs (or Establishment Costs)

This establishment cost has a two-fold objective: minimize the costs related to the establishment of a new plant, warehouse, and distribution center; or minimize the costs

related to the maintenance of the infrastructure to keep the facilities operating at the appropriate capacity level. Here are the corresponding terms in the objective function:

$$\sum_p I_p\, Y_p \quad + \quad \sum_w I_w\, Y_w \quad + \quad \sum_d I_d\, Y_d$$

The binary variables (Y) are necessary to allow these costs to enter the objective function only if the corresponding facilities are part of the optimal solution. The costs are to be incurred either the network sites have already been established or have only been pre-selected.

Production Costs

The production cost incurred at plant p has to do with the direct costs per unit at a constant rate of production. The corresponding term in the objective function is described here:

$$\sum_p C_p\, Q_p$$

Because this is a global supply chain network model, it is implied that each production cost accounts for the wage, payroll taxes, fringe benefits, input, utility, and technology cost differences.

Material Handling Costs

This material handling cost is related to the cost of the loading and unloading activities, as well as the handling activities to store and pick up products inside the warehouses and distribution centers. The corresponding terms in the objective function are:

$$\sum_w H_w \left(\sum_p Q_{pw} \right) \quad + \quad \sum_d H_d \left(\sum_w Q_{wd} \right)$$

The term shows the sum of the total rate of flow leaving (arriving at) a warehouse w multiplied by its corresponding handling cost per ton H_w, this cost is adjusted ahead of time ($H_w = H_w \div TON$ and $H_d = H_d \div TON$), and the total rate of flow leaving (arriving at) a distribution center d multiplied by its corresponding handling cost per unit H_d.

Transportation Costs

This transportation cost is a linear function of the flow of material between nodes. It denotes the cost per ton/mile to transport materials from a pick-delivery point that can be a port terminal, the facility itself, a storage dock, a railroad station or a barge terminal. The unit cost is multiplied by the distance and by the flow of materials per transportation link:

$$\sum_{p,w} Q_{pw}\, C_{pw}\, DT_{pw} \quad + \quad \sum_{w,d} Q_{wd}\, C_{wd}\, DT_{wd} \quad + \quad \sum_{d,z} Q_{dz}\, C_{dz}\, DT_{dz}$$

Due to the fact that this model is dealing with one single commodity type product with a high volume hauling modes, a piecewise linear function is not made necessary.

Tariffs and Duties with Adjustment Factor

The charges of tariffs and duties take place at the destination by using the transfer price of the material originator. It denotes the cost as a percentage of the total financial transaction, based on the transfer price per ton adjusted ahead of time ($TP_p = TP_p \div TON$ and $TP_w = TP_w \div TON$) to transport materials from plants to warehouses and from warehouses to distribution centers. The tariffs and duties at the corresponding customer zone are not being considered because of the diverse number of countries that a zone can take. An adjustment factor (AF^T) with a value of 10 is multiplied to ensure efficacy of this term in the objective function as follows:

$$\sum_p \sum_w \mathrm{T}_w \ \mathrm{TP}_p \ \mathrm{AF}^{\mathrm{T}} \quad + \quad \sum_w \sum_d \mathrm{T}_d \ \mathrm{TP}_w \ \mathrm{AF}^{\mathrm{T}}$$

These costs can be easily eliminated from the model by changing the percentage values into zeros.

Lead Time Value

The lead time to deliver the products between echelons is also taken into account by this network model. It denotes a numeric value that represents the number of days to receive, handle and deliver the materials to their optimal destination. An adjustment factor ($\mathrm{AF}^{\mathrm{LT}}$) with a value of 2400 is multiplied to ensure efficacy of this term in the objective function as well:

$$\sum_{p,w} \mathrm{X}_{pw} \ \mathrm{LT}_{pw} \ \mathrm{AF}^{\mathrm{LT}} \quad + \quad \sum_{w,d} \mathrm{X}_{wd} \ \mathrm{LT}_{wd} \ \mathrm{AF}^{\mathrm{LT}} \quad + \quad \sum_{d,z} \mathrm{X}_{dz} \ \mathrm{LT}_{dz} \ \mathrm{AF}^{\mathrm{LT}}$$

Freedom Index Cost

The freedom to do business in a certain region of the globe is captured here by means of the index of economic freedom by the Heritage Foundation. The highest ranks signify the sound environment that business should encounter when dealing with issues related to property right, freedoms of movement of labor, capital, and goods, and consumer protection. The index of economic freedom is an average of 10 broad factors of economic freedom: business, trade, monetary, freedom from government, fiscal, property rights, investment, financial, freedom from corruption, and labor freedom. The index is subtracted by 100 to account for the minimization of the objective function ($F_p' = 100 - F_p$, $F_w' = 100 - F_w$, $F_d' = 100 - F_d$). The corresponding terms in the objective function are:

$$\sum_p \mathrm{I}_p \ (100 - \mathrm{F}_p) \ \mathrm{Y}_p \quad + \quad \sum_w \mathrm{I}_w \ (100 - \mathrm{F}_w) \ \mathrm{Y}_w \quad + \quad \sum_d \mathrm{I}_d \ (100 - \mathrm{F}_d) \ \mathrm{Y}_d$$

The **Overall Objective Function** to be used by the model and displayed as the optimal (minimal) solution is a combination of all these preliminaries terms. The total cost of the supply chain network is a symbolic value because of the use of lead times, which do not represent monetary values. The objective of the global supply chain distribution network is to minimize the following function:

$$
\min \quad \sum_p I_p Y_p \; + \; \sum_w I_w Y_w \; + \; \sum_d I_d Y_d \; + \; \sum_p C_p Q_p \; + \; \sum_w H_w \left(\sum_p Q_{pw} \right) +
$$

$$
\sum_d H_d \left(\sum_w Q_{wd} \right) + \sum_{p,w} Q_{pw} C_{pw} + \sum_{w,d} Q_{wd} C_{wd} \; + \; \sum_{d,z} Q_{dz} C_{dz} \; + \; \sum_p \sum_w T_w \; TP_p \; AF^T
$$

$$
+ \; \sum_w \sum_d T_d \; TP_w \; AF^T + \sum_{p,w} X_{pw} \; LT_{pw} \; AF^{LT} \; + \; \sum_{w,d} X_{wd} \; LT_{wd} \; AF^{LT} \; + \; \sum_{d,z} X_{dz} \; LT_{dz} \; AF^{LT}
$$

$$
+ \; \sum_p I_p \; F_p' Y_p \; + \; \sum_w I_w \; F_w' Y_w \; + \; \sum_d I_d \; F_d' Y_d
$$

This model seems to be a logical representation of a deterministic global supply chain network for the minimization of costs that are incurred when goods are transferred around different regions of the globe. It does not account for uncertainties in product demands and material handling. Tsiakis and Pantelides (2001) took those uncertainties into consideration in their model.

CHAPTER 3 - MICROSOFT® EXCEL MIXED-INTEGER APPLICATION

The objective of this project is to implement a strategic planning model using Microsoft Excel Solver (Premium Simplex) for the selection of worldwide manufacturing sites, distribution sites, transportation nodes and flow of products between nodes at an agribusiness company for a single commodity. The mixed-integer model will select manufacturing sites, warehouses, distribution centers and retail facilities, and then will assume these selected sites fixed for a subsequent re-optimization. The model can identify if existing facility locations and logistics structure are optimal for the company to minimize operational costs. Also, a supplemental mixed-integer model will help select all related sites by means of the Economic Freedom Index. Sensitivity analysis will be presented subsequently in chapter 5.

The proposed global supply chain model is to be implemented by means of a few major tasks:

- Make use of a mixed-integer model formulation for global supply chain strategic planning in Excel assuming potential manufacturing sites, warehouse facilities and distribution centers.

- Modify and analyze the mixed-integer model assuming selected, optimal manufacturing sites as fixed locations for the global supply chain strategic planning.

It has been thought that multi-national distribution networks depend on several different factors including political instability, trade barriers, local content rules, general infrastructure, monetary exchange rates, tariffs, duties, export taxes, and transfer prices to be

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effectively optimal. The Microsoft® Excel model made use of some of these factors that are by all means country-dependent values.

The Premium Solver Platform for Excel® that I used for the Global Supply Chain Network Model can analyze and interpret a model in ways not possible with Microsoft Excel® alone. It is designed to analyze and solve *much larger* models, *faster* than ever before.

The basic purpose of the Solver is to find a *solution* – that is, values for the *variables* or Changing Cells in the model – that satisfies the *constraints* and that maximizes or minimizes the *objective* or Set Cell value (if there is one). This famous approach of task optimization is also known as Linear Programming. However, a Mixed-Integer Programming is very common for dealing with facility locations and holding inventories.

I started the design of the model in Excel by means of a **Main Menu** that gives me, and any prospective user, the ability to get around several different areas of the model building worksheets. The menu contains links, or menu options, to the following areas of the Excel model (See Figure 4):

- Plants: facilities around the world where the product has been manufactured, processed, or simply collected to be distributed to several warehouses.

- Warehouses: facilities around the world where the product is to be selected, stored, graded, or simply cross-docked to be shipped to the optimal distribution centers.

- Distribution centers: storage facilities that serve nearby customers on their product demand needs in a timely manner.

- Customer zones: markets where there is demand for the products. It consists of a combination of markets that may include several provinces or states of one

particular country, or a number of countries pertaining to a certain geographic region. Zones should be selected based on economic clusters (regions) with greater population density.

- Summary: it displays optimal data pulled out from the model that can help me identify areas of improvement as well as total values of component terms in the objective function.

- Charts: it displays the optimal flow of materials (continuous decision variables) from plants to warehouses, to distribution centers, to customer zones.

- Transportation data: it links to a secondary menu that contains links to other areas of the model to be entered input data on transportation link capacity, distance, costs and lead time.

- Parameters: it allows me to change the commodity that is being used for the model, to enter the transportation costs per ton/mile on each mode, and to change the assumptions of fixed locations and validity of the Economic Freedom Index.
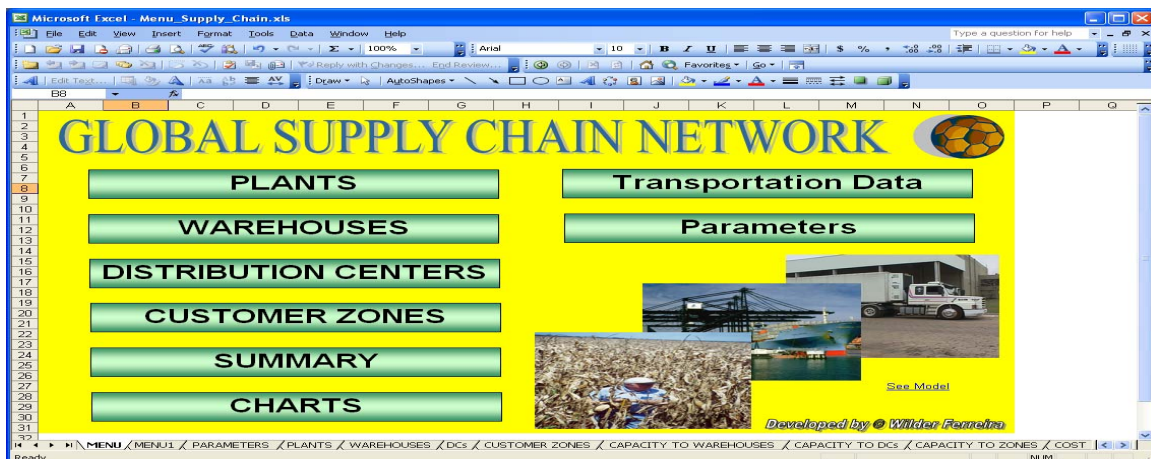
Fig. 4 – Main Menu in the Microsoft® Excel model.

The worksheet area for Plant data input allows me to enter the unit cost (C_p = unit production cost of plant p), the transfer price which is later converted into a price per ton (TP_p = transfer price of the product at plant p), the investment or fixed cost (I_p = annualized fixed cost of establishing or maintaining a plant p), the minimum capacity (P_p^{min} = minimum production capacity of plant p), the maximum capacity (P_p^{max} = maximum production capacity of plant p), and the Freedom Index in its true value which is later converted into the model to F_p by subtracting it by 100. See Figure 5.

Fig. 5 – Worksheet Area for Plant Data in the Microsoft® Excel model.

The worksheet area for Warehouse data input allows me to enter the handling cost (H_w = unit handling cost at warehouse w), the transfer price which is later converted into a price per ton (TP_w = transfer price of the product at warehouse w), the investment or fixed cost (I_w = annualized fixed cost of establishing or maintaining a warehouse w), the duties and

tariffs (T_w = tariffs as a % of the total price of materials shipped to warehouse w), the minimum capacity (W_w^{min} = minimum material handling capacity at warehouse w), the maximum capacity (W_w^{max} = maximum material handling capacity at warehouse w), and the Freedom Index in its true value which is later converted into the model to F_w by subtracting it by 100. See Figure 6.

Fig. 6 – Worksheet Area for Warehouse Data in the Microsoft® Excel model.

The worksheet area for Distribution Center data input allows me to enter the handling cost (H_d = unit handling cost at distribution center d), the transfer price which is later converted into a price per ton (TP_d = transfer price of the product at distribution center d), the investment or fixed cost (I_d = annualized fixed cost of establishing or maintaining a distribution center d), the duties and tariffs (T_d = tariffs as a % of the total price of materials

shipped to distribution center d), the minimum capacity (DC_d^{min} = minimum material handling capacity at distribution center d), the maximum capacity (DC_d^{max} = maximum material handling capacity at distribution center d), and the Freedom Index in its true value which is later converted into the model to F_d by subtracting it by 100. See Figure 7.

Fig. 7 – Worksheet Area for Distribution Center Data in the Microsoft® Excel model.

The worksheet area for Customer Zone data input allows me to enter the demand of each zone (D_z = demand for the product in customer zone z). See Figure 8.

Fig. 8 – Worksheet Area for Customer Zone Data in the Microsoft® Excel model.

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The sub-menu on Transportation Data is shown in Figure 9. They allow me to enter the information requested by the model dealing with several transportation link constants, including capacity, cost, distance, and lead time.

Fig. 9 – Sub-menu for Transportation Link Data in the Microsoft® Excel model.

The worksheet area for Transportation Capacity (Plants to Warehouses) data input allows me to enter the maximum capacity between the two echelons (L_{pw}^{max} = maximum rate of flow from plant p to warehouse w). See Figure 10.
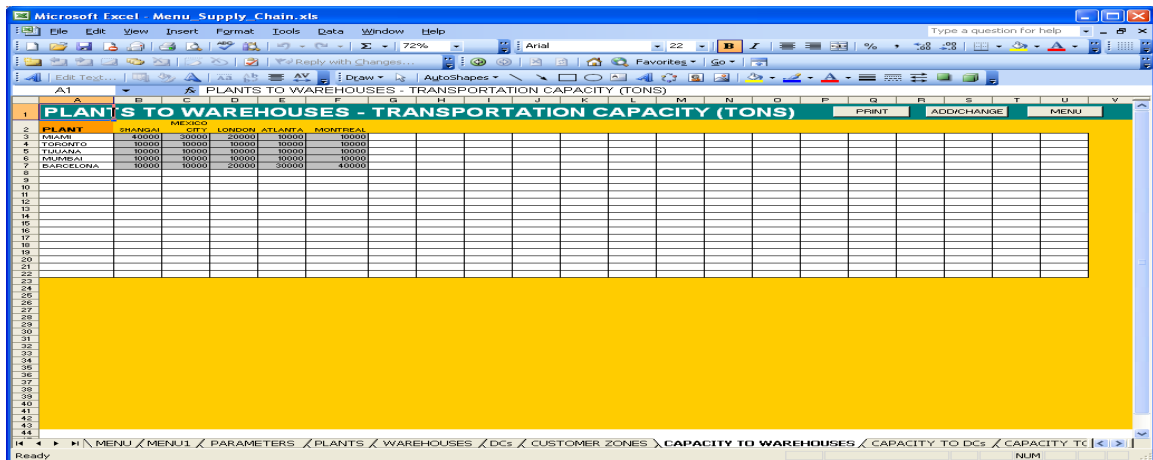
Fig. 10 – Worksheet Area for Transportation Capacity from Plants to Warehouses.

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The worksheet area on Capacity from Warehouses to Distribution Centers allows me to enter the maximum capacity between these two echelons (L_{wd}^{max} = maximum rate of flow from warehouse w to distribution center d). See Figure 11.
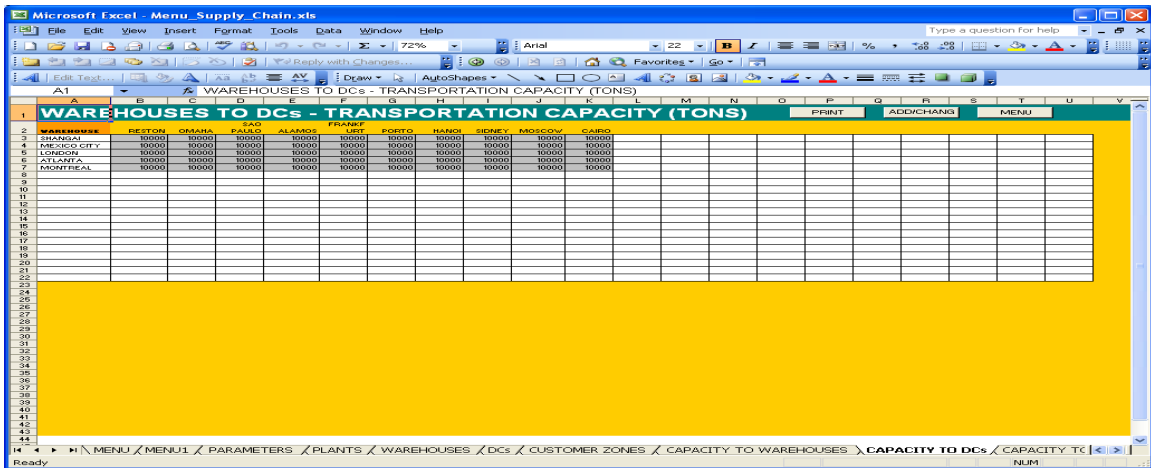
Fig. 11 – Worksheet Area for Transportation Capacity from Warehouses to DCs.

Lastly, the worksheet area for Capacity between Distribution Centers and Customer Zones also allows me to enter the maximum capacity between these echelons (L_{dz}^{max} = maximum rate of flow from distribution center d to customer zone z). See Figure 12.
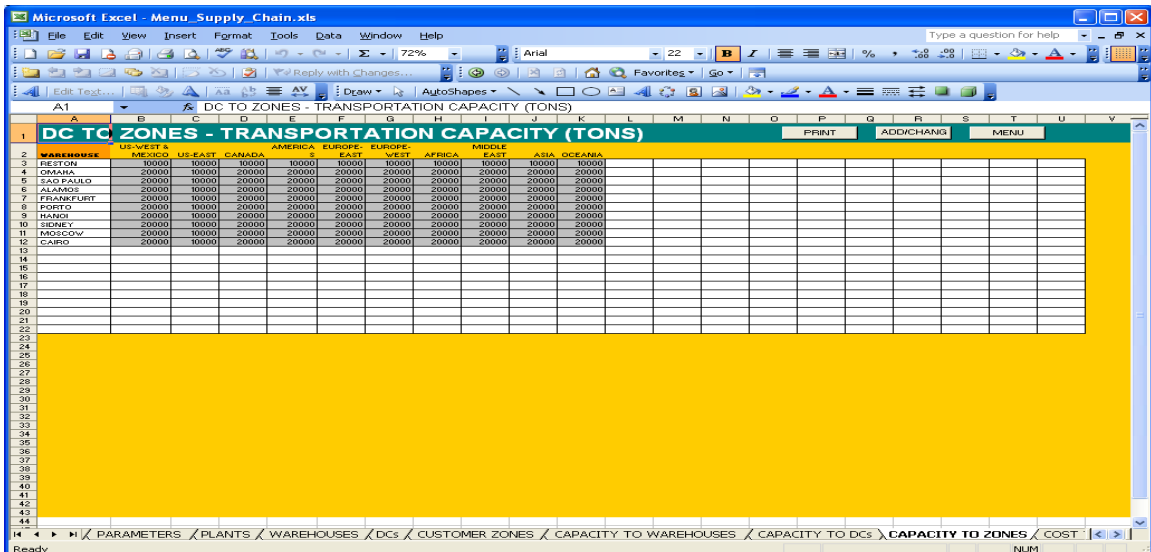
Fig. 12 – Worksheet Area for Transportation Capacity from DCs to Customer Zones.

The next nine following worksheet areas relate to cost, distance and lead time. They are not displayed in this chapter because of the similarity to Figure 12, but the constants that can be entered are shown next:

— C_{pw} = transportation cost from plant p to warehouse w, C_{wd} = transportation cost from warehouse w to distribution center d, C_{dz} = transportation cost from distribution center d to customer zone z, DT_{pw} = distance in miles between plant p and warehouse w, DT_{wd} = distance in miles between warehouse w and distribution center d, DT_{dz} = distance in miles between distribution center d and customer zone z, LT_{pw} = transportation lead time from plant p to warehouse w, LT_{wd} = transportation lead time from warehouse w to distribution center d, and LT_{dz} = transportation lead time from distribution center d to customer zone z.

Also, the charts and the summary screens are not displayed in this chapter because they are better suited for being displayed in Chapter 5 that deals with the optimal solutions and sensitivity analysis. However, the worksheet area for the model Parameters is shown in Figure 13. It allows me to change the commodity that can be corn, wheat, soybeans, coffee, or any other commodity I decide to enter later on; the revenue unit which by default can be bushel, pound, or ton, with the allowance to add any measurement of yield or transportation unit later on; the conversion factor to pounds when the revenue unit is not pound; the conversion factor to tons for changing the transfer price into tons (TON); the general U.S. rail, truck and ocean ship rates to be displayed as a prompt at the appropriate worksheet area; the option whether to include the Freedom Index or not; and the option to make this

model a network of fixed (existing and operating) facilities or a model of pre-selected facilities that may become part of network.
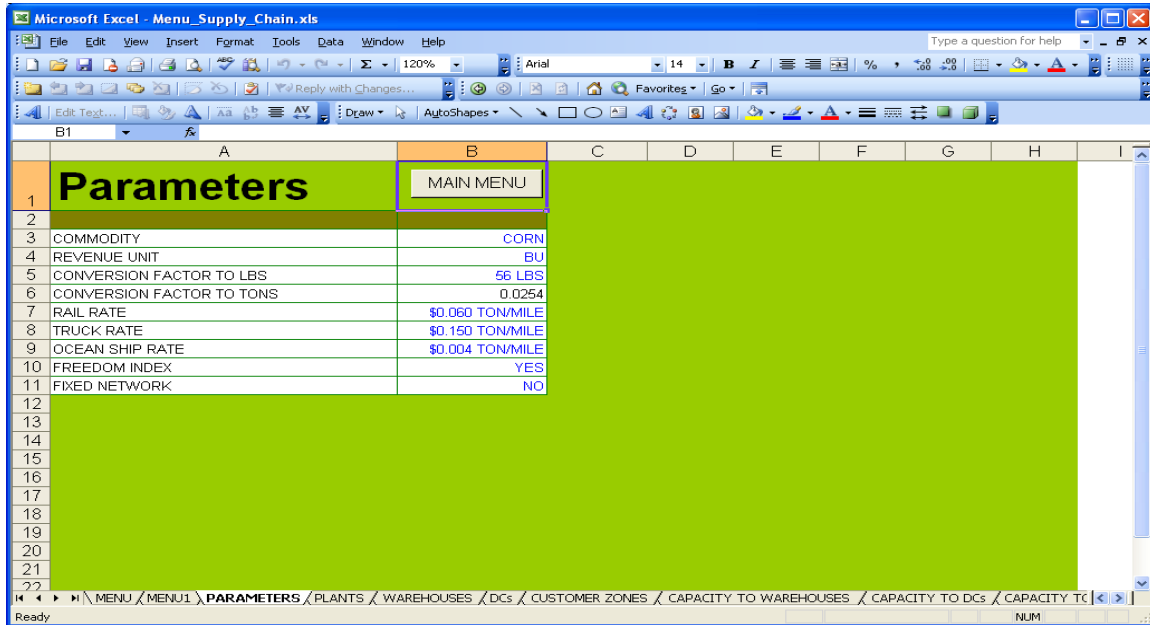
Fig. 13 – Worksheet Area for Parameters in the Microsoft® Excel model.

For a linear programming model to be executed by the Solver, it is necessary that all the inputs (variables, constants, formulas, limits, binary numbers) be part of the same worksheet. Thus, the worksheet named MODEL will contain all the data to be used by the Solver. For me to make all the inputs that were entered in the respective worksheet areas be displayed in the same worksheet (MODEL), I had to create Visual Basic Application (VBA) codes. The respective codes are displayed in APPENDIX B. Consequently, all the data that have been transferred to the worksheet MODEL will be presented next. In Figure 14, it is depicted the model from rows 3 to 70. These worksheet rows (as well as columns) will stretch farther given that the model can be expanded in terms of number of plants, warehouses, distribution centers and customers zones. The green-shaded area corresponds to the continuous decision variables with their respective names in the worksheet: (Q_p =

PlantDV, Q_{pw} = PlantWarehouseDV, Q_{wd} = WarehouseDCDV, and Q_{dz} = DCZoneDV). Accordingly, the aqua-shaded area corresponds to the logical constraints for facility and plant production capacities as well as the material balance constraints, with the following names in the worksheet: flow of materials leaving each plant ($\sum_w Q_{pw}$ =Sum_Plants), flow of materials leaving each warehouse ($\sum_p Q_{pw}$ = Sum1_Warehouses), flow of materials entering each distribution center ($\sum_d Q_{wd}$ =Sum2_Warehouses), flow of material leaving each distribution center ($\sum_w Q_{wd}$ =Sum1_DCs), flow of materials entering each customer zone ($\sum_z Q_{dz}$ =Sum2_DCs), and flow of material received by each customer zone ($\sum_d Q_{dz}$ =Sum1_Zones). In worksheet MODEL, the input data on Plants are displayed within their respective highlighted session Plants and named accordingly: the production unit cost (C_p = CostUnit), transfer price per ton ($TP_p \div TON$ = PlantTransferPrice), fixed cost (I_p = PlantFixedCost), the inverse of the Freedom Index ($100 - F_p$ = PlantFreedom), the plant binary variable (Y_p = PlantBinary), the minimum plant capacity if it exists ($P_p^{min} Y_p$ = PlantMin), and the maximum plant capacity if it exists ($P_p^{max} Y_p$ = PlantMin).

Still in worksheet MODEL (Fig. 14), the input data on Warehouses are displayed within their respective highlighted session Warehouse. It is displayed the handling cost per ton ($H_w \div TON$ = WarehouseHandlingCost), transfer price per ton (TP_w / TON = WarehouseTransferPrice), fixed cost (I_w = WarehouseFixedCost), the inverse of the

Freedom Index (100-F_w = WarehouseFreedom), the warehouse binary variable (Y_w = WarehouseBinary), the minimum warehouse material handling capacity if it exists (W_w^{min} Y_w = WarehouseMin), and the maximum warehouse material handling capacity if it exists (W_w^{max} Y_w = WarehouseMax). See Figure 14.
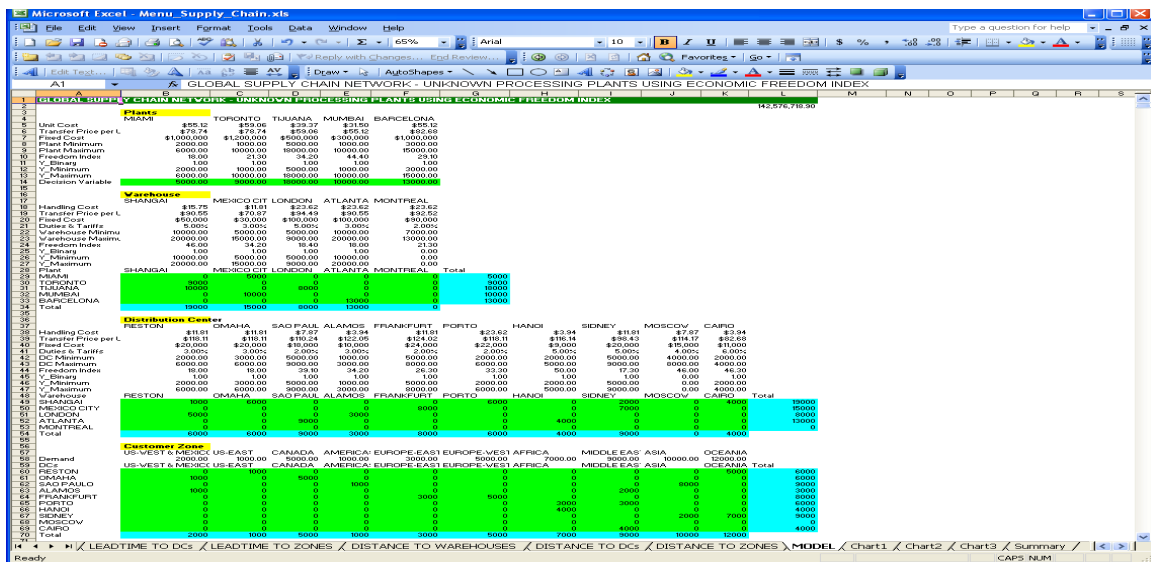
Fig. 14 – Worksheet MODEL with Continuous Decision Variables (Q) and Facility Input data.

Also in worksheet MODEL (Fig. 14), the input data on Distribution Centers are displayed within their respective highlighted session Distribution Center. It is also displayed the handling cost per ton ($H_d \div$ TON = DCHandlingCost), transfer price per ton (TP_d / TON = DCTransferPrice), fixed cost (I_d = DCFixedCost), the inverse of the Freedom Index (100-F_d = DCFreedom), the distribution center binary variable (Y_d = DCBinary), the minimum distribution center material handling capacity if it exists (DC_d^{min} Y_d =

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DCMin), and the maximum distribution center material handling capacity if it exists (DC_d^{max}

Y_d = DCMax).

Finally, also in Figure 14, it is displayed the demand input data of each customer zone (D_z = CustomerDemand) within the respective highlighted session Customer Zone.

In Figure 15, it is depicted all the link binary decision variables in the olive-shaded area with the following names in the worksheet: X_{pw} = PlantWarehouseDV_X, X_{wd} = WarehouseDCDV_X, and X_{dz} = DCZoneDV_X. Also, it displays the network structure constraint values ($\leq$ RHS), as a multidimensional matrix, in the mediumvioletred-shaded areas with the following names: PlantWarehouse_Y ($X_{pw} \leq Y_p$), PlantWarehouse_Y2 ($X_{pw} \leq Y_w$), WarehouseDC_Y ($X_{wd} \leq Y_w$), WarehouseDC_Y2 ($X_{wd} \leq Y_d$), and DCZone_Y ($X_{dz} \leq Y_d$). See Figure 15.
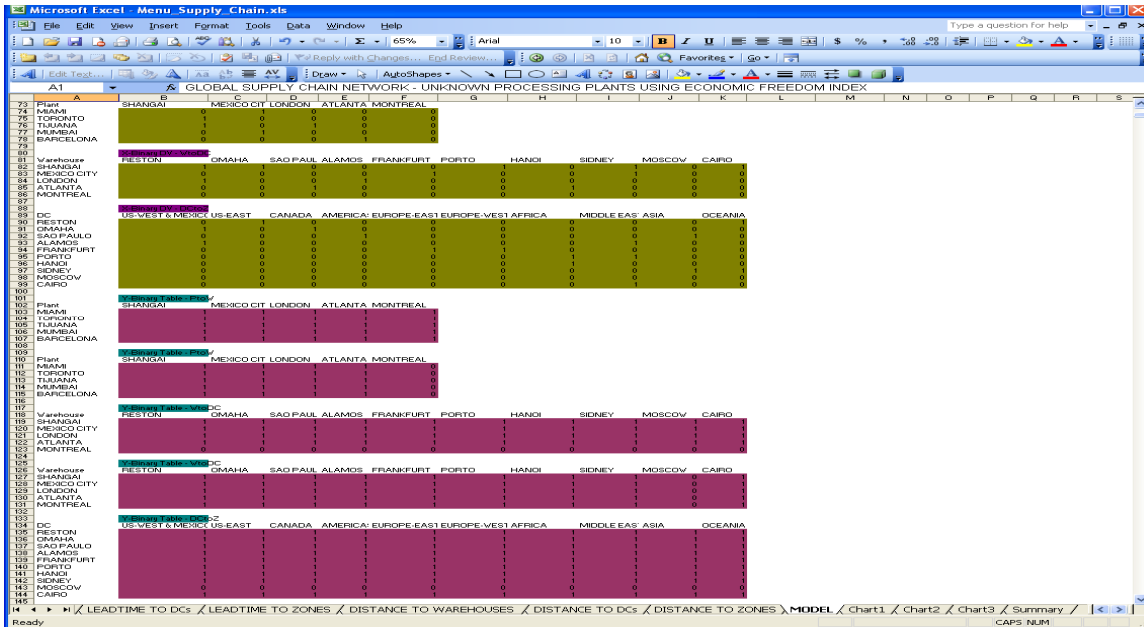
Fig. 15 – Worksheet MODEL with Binary Decision Variables (Y) and Network Structure Constants.

In Figure 16, it displays in the green-shaded areas the constraint values ($\leq$ RHS), for the logical constraints for transportation flows when the respective links exist: ($\leq L_{pw}^{max}$ X_{pw} = PlantWarehouse_MaxCapacityX), ($\leq L_{wd}^{max}$ X_{wd} = WarehouseDC_MaxCapacityX), and ($\leq L_{dz}^{max}$ X_{dz} = DCZone_MaxCapacityX). Also, it displays the lead time to deliver the products between echelons multiplied by an adjustment factor (AF^{LT}) of 2400 in the olive-shaded areas with the following names: PlantWarehouse_LeadTime (LT_{pw} AF^{LT}), WarehouseDC_LeadTime (LT_{wd} AF^{LT}), and DCZone_LeadTime (LT_{dz} AF^{LT}).
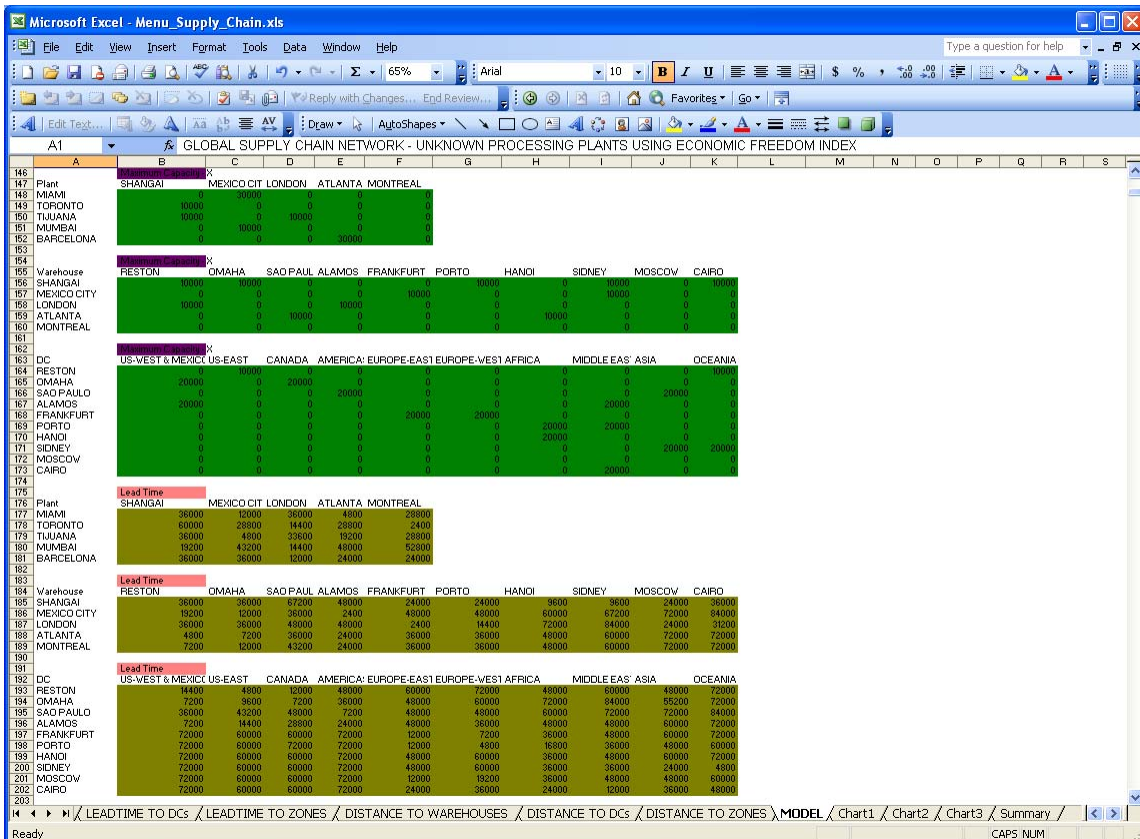
Fig. 16 – Worksheet MODEL with Maximum Facility Capacities and Link Lead Times.

In Figure 17, in the bright green-shaded areas, the transportation flow costs multiplied the actual distance in miles are displayed and named according to their echelon levels: plants to warehouses ($C_{pw}\,DT_{pw}$ = PlantWarehouse_Cost), warehouses to distribution centers ($C_{wd}\,DT_{wd}$ = WarehouseDC_Cost), and distribution centers to customer zones ($C_{dz}\,DT_{dz}$ = DCZone_Cost). Also, it displays the value of the tariffs and duties to be charged at the destination multiplied by an adjustment factor (AF^T) of 10 in the violet-shaded areas with the following names: plants to warehouses ($T_w\,TP_p\,AF^T$ = PlantWarehouse_Tariffs), and warehouses to distribution centers ($T_d\,TP_w\,AF^T$ = WarehouseDC_Tariffs). See Figure 17.
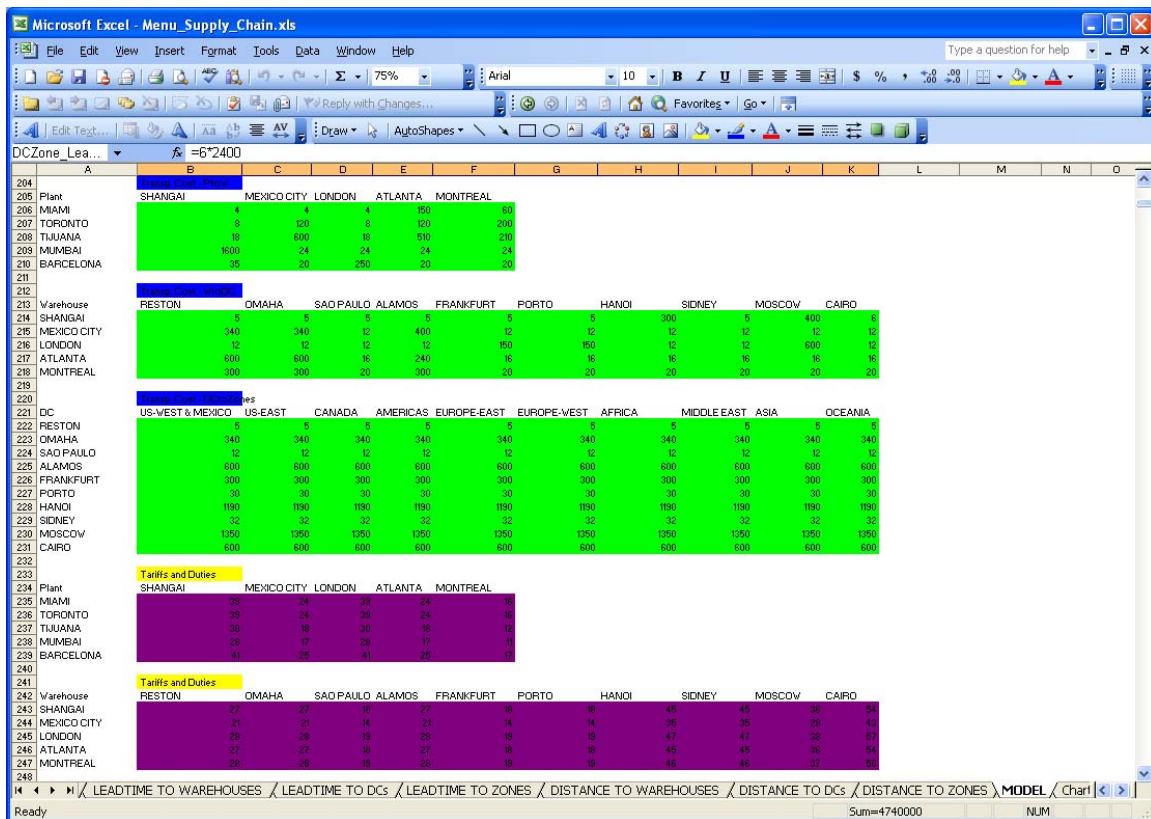
Fig. 17 – Worksheet MODEL with Transportation Costs, and Tariffs and Duties.

This is the last matrix of the Excel model. It is still not possible to run the Solver Platform because the model has not been entered, yet. To enter the objective function, the

decision variable and the constraints into the Solver content area, I must evoke the application first. It is important to bear in mind that I named all the cell ranges in Excel that will be used in the global supply chain model. Thus, it will be just a matter of typing in the range names at their respective places inside the Solver input areas. In Figure 18, the three input areas are clearly displayed: Set Cells (Objective Function), By Changing the Variable Cells (Decision Variables) and Subject to the Constraints (Constraints). Except for the range name "objectivefunction," all the other names have already been displayed in this chapter.
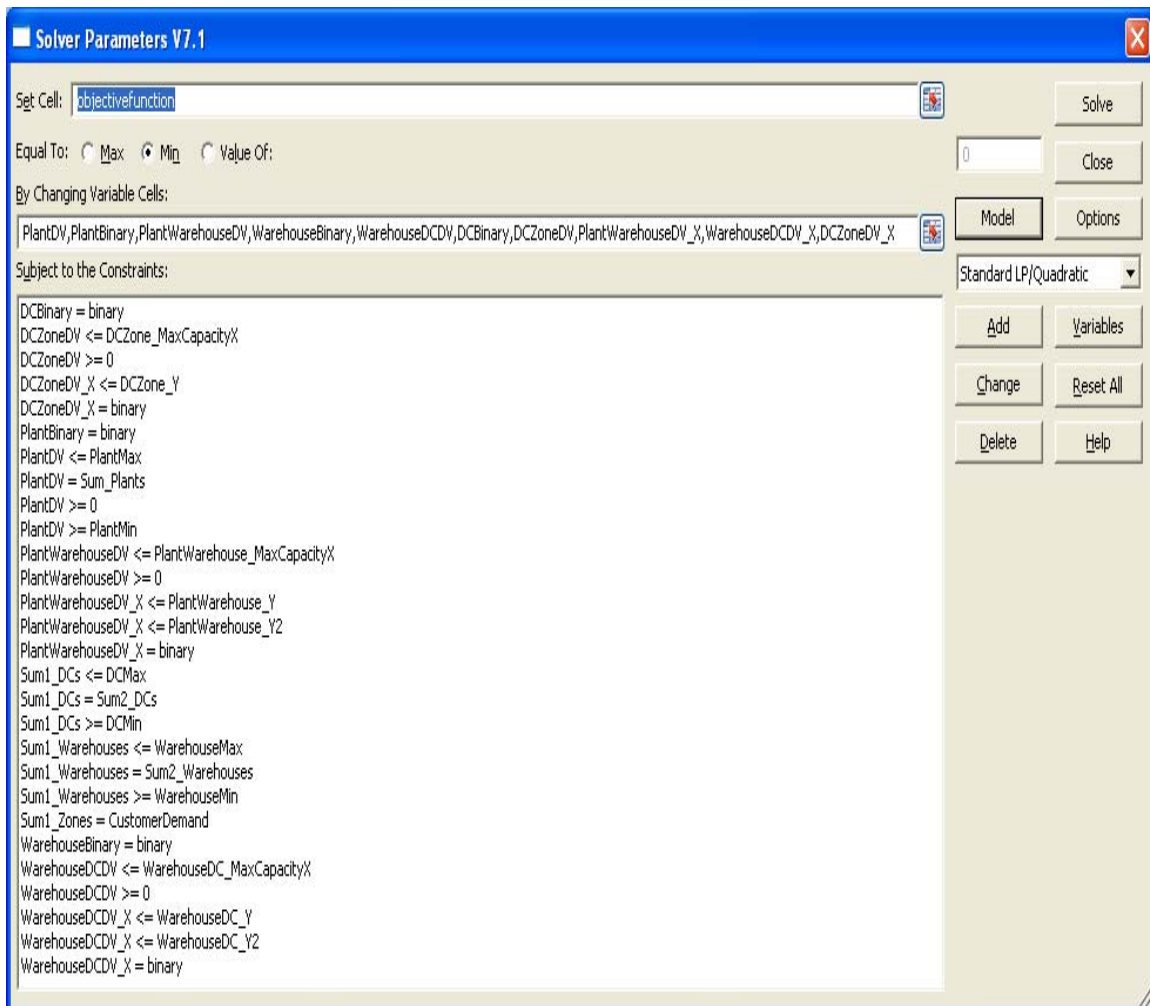
Fig. 18 – Solver Platform in Worksheet MODEL

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Thus, the objective function showed in Chapter 2 is now used in cell L2 (=objectivefunction) to address the minimum operational value for material flow from a global distribution network. The seven components terms of the objective function are : Production Costs + Fixed Infrastructure Costs + Material Handling Costs + Freedom Index Cost + Transportation Costs + Tariffs and Duties with Adjustment Factor + Lead Time Value. Inside cell L2, a series of SUMPRODUCT() functions are utilized to calculate each component value and summed up to obtain the total value of the objective function. The cell L2 in worksheet MODEL contains the following Excel mathematical functions:

=SUMPRODUCT(CostUnit,PlantDV)

+SUMPRODUCT(PlantBinary,PlantFixedCost)

+SUMPRODUCT(WarehouseBinary,WarehouseFixedCost)+

SUMPRODUCT(DCBinary,DCFixedCost)+

SUMPRODUCT(Sum1_Warehouses,WarehouseHandlingCost)+

SUMPRODUCT(Sum1_DCs,DCHandlingCost)+

SUMPRODUCT(PlantBinary,PlantFixedCost,PlantFreedom)+

SUMPRODUCT(WarehouseBinary,WarehouseFixedCost,WarehouseFreedom)+

SUMPRODUCT(DCBinary,DCFixedCost,DCFreedom)+

SUMPRODUCT(PlantWarehouseDV,PlantWarehouse_Cost)+

SUMPRODUCT(WarehouseDCDV,WarehouseDC_Cost)+

SUMPRODUCT(DCZoneDV,DCZone_Cost)+

SUMPRODUCT(PlantWarehouseDV,PlantWarehouse_Tariffs)+

SUMPRODUCT(WarehouseDCDV,WarehouseDC_Tariffs)+

SUMPRODUCT(PlantWarehouseDV_X,PlantWarehouse_LeadTime)+

SUMPRODUCT(WarehouseDCDV_X,WarehouseDC_LeadTime)+

SUMPRODUCT(DCZoneDV_X,DCZone_LeadTime)

Thus, the objective function showed in Chapter 2 is now used in cell L2 (=objectivefunction) to address the minimum operational value for material flow from a global distribution network. The seven components terms of the objective function are : Production Costs + Fixed Infrastructure Costs + Material Handling Costs + Freedom Index Cost + Transportation Costs + Tariffs and Duties with Adjustment Factor + Lead Time Value.

CHAPTER 4 - IMPLEMENTATION

This project is about the implementation of a strategic global supply chain planning model using Microsoft Excel Solver (Premium Simplex). The optimal solution will depend on a combination of inputs that are to be gathered through research effort without actually making use of a particular firm. An agricultural commodity is to be selected and the various prices and costs associated with the transfer and hauling of all the material collected via the Internet and phone calls. The convenience of use of these commodities is a great asset because of the uncomplicated data collection process. All the information necessary to run this model is available on the Internet from various governmental and private agencies. This Excel mixed-integer model will select manufacturing sites, warehouses, distribution centers and retail facilities, and then will assume these selected sites fixed for a subsequent re-optimization in Chapter 5. In this chapter, I will make use of the model for global supply chain strategic planning assuming potential manufacturing sites, warehouse facilities and distribution centers.

The use of the Premium Solver Platform for Excel is extremely important because it can handle up to 8000 decision variables, 8000 constraints and 2000 integers. It can analyze and interpret a model in ways not possible by Microsoft® Excel Solver add-in. See Figure 19. It has options for the modeler to limit the number of feasible solutions, set the maximum tolerance level, and establish the desired cuts and heuristics. Cut involves the automatic generation of additional constraints, or "cuts," that reduce the size of the feasible region for the optimization sub-problems that must be solved, without eliminating any potential integer

solutions. Heuristics are "rules of thumb" that may often, but not always, succeed in achieving a given result. See Figure 20.
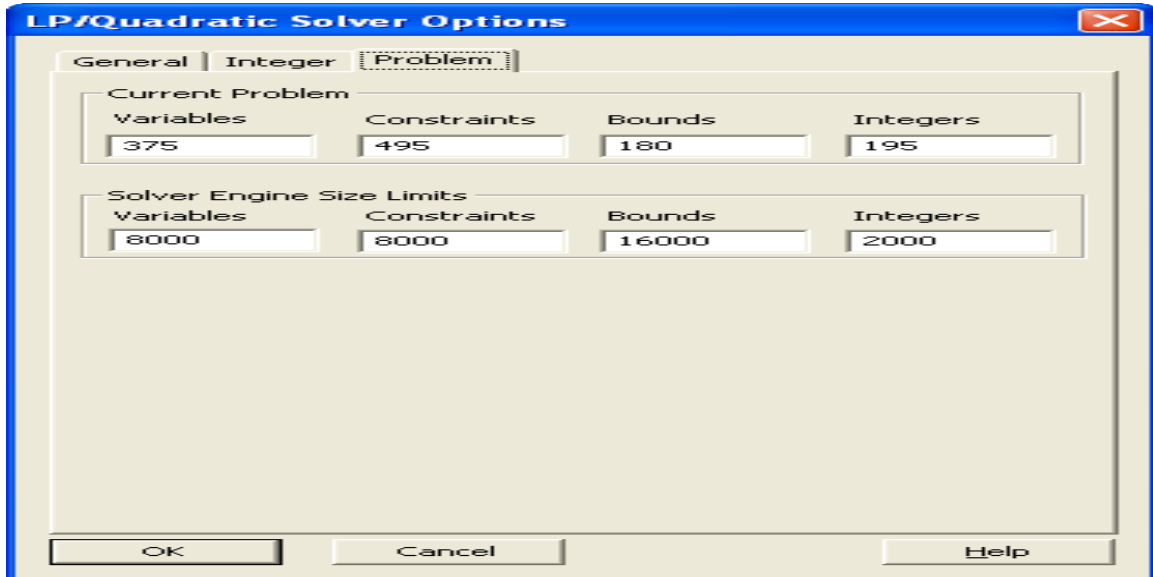
Fig. 19–Solver Platform: LP/Quadratic Solver Options (Problem)
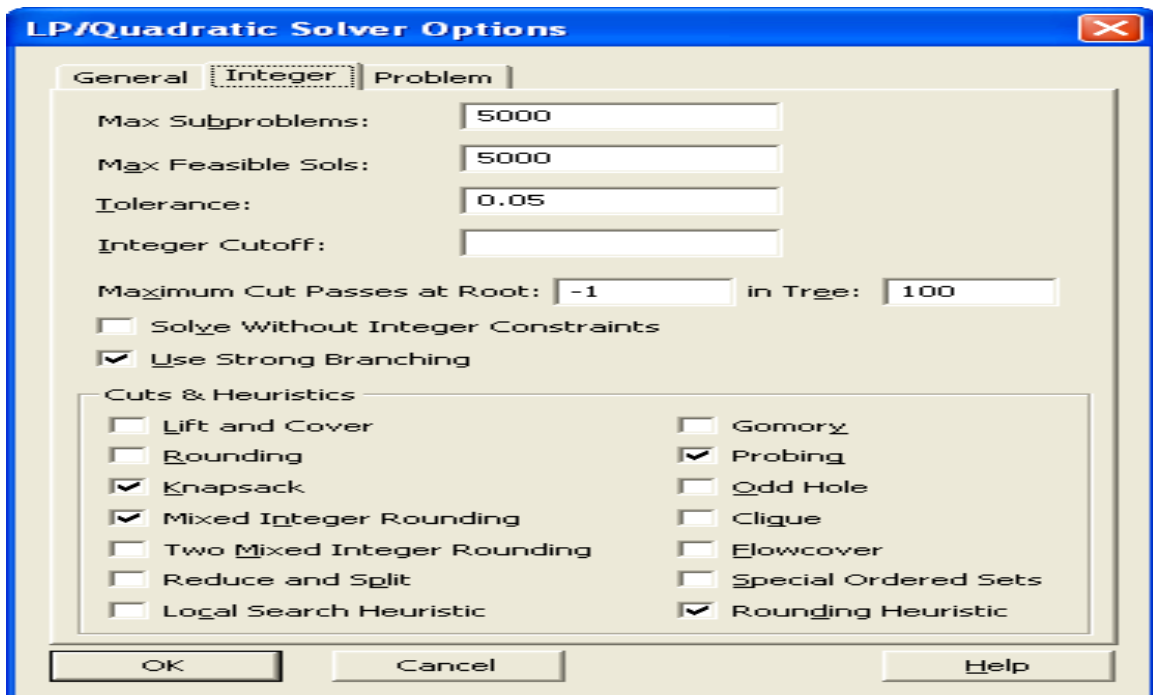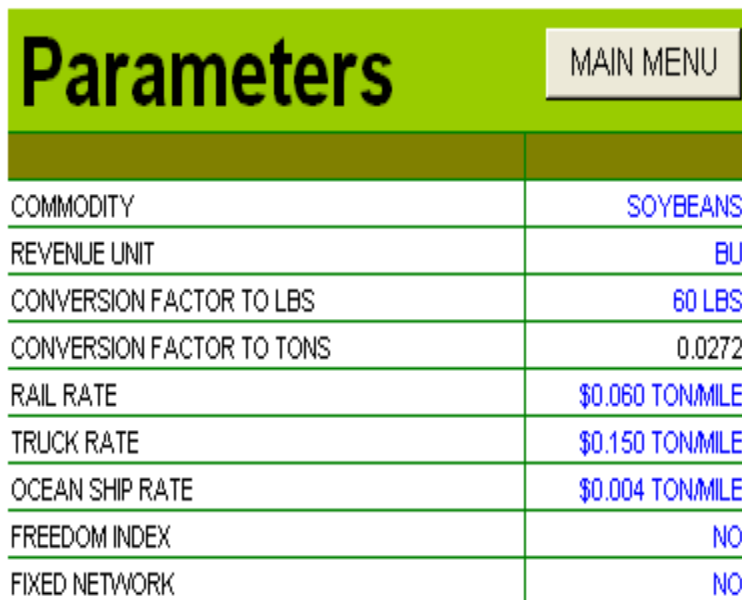
Fig. 20–Solver Platform: LP/Quadratic Solver Options (Integer)

This multi-national distribution network deals with political, social, economic and trade instability that I had to address by means of the Heritage Foundation's Economic Freedom Index http://www.heritage.org/index/countries.cfm. Here is the 2008 index for the following existing countries in the model: USA (80.6), Canada (80.2), Mexico (66.4), India (54.2), China (52.8), United Kingdom (79.5), Brazil (55.9), Germany (71.2), Portugal (64.3), Vietnam (49.8), Australia (82), Russia (49.9) and Egypt (59.2). With that in mind, we ascertain that making business in these countries might impose risks to the company that is looking for strategic business expansions. The commodity Soybeans has been selected for this model because of its worldwide use, multiple production areas and ease of gathering data. Figure 21 shows the parameters that are needed to be selected to customize the model:

Parameters	MAIN MENU
COMMODITY	SOYBEANS
REVENUE UNIT	BU
CONVERSION FACTOR TO LBS	60 LBS
CONVERSION FACTOR TO TONS	0.0272
RAIL RATE	$0.060 TON/MILE
TRUCK RATE	$0.150 TON/MILE
OCEAN SHIP RATE	$0.004 TON/MILE
FREEDOM INDEX	NO
FIXED NETWORK	NO

Fig. 21–Parameters Data in the Microsoft® Excel model

The model assumes transportation from port-to-port among some countries, thus the rate of $0.004 per ton/mile will be utilized for finding out the transportation costs from an echelon to the next. Rail and truck rates of $0.060 and $0.150 per/ton mile, respectively,

will be utilized to address costs of transportation when these modes are available between echelons. In the future, they can be used for the model to be able to select which transportation mode is more cost-efficient between a pair of distribution sites. We will first run the model without the Freedom Index (FREEDOM INDEX = NO) and assume the network is not fixed (FIXED NETWORK = NO). Assuming no fixed network implies that any plant site can be selected to manufacture or distribute the product. The conversion factor to tons of 0.0272 will be utilized to convert the production costs, handling costs and transfer prices from pounds into tons because the decision variables to be found will be measured in tons.

The transportation data are crucial for this model to be feasible and capable of obtaining meaningful results. The data that corresponds to transportation links can be entered individually and displayed later in the decision model. The categories are: distance, cost, capacity and lead time. Transportation costs from plants to warehouses have been entered based on the transportation mode that seems viable between facilities. For example, a ship container should be transported from the port in Miami to the port in Shangai, whereas truck loads should be used between Miami and Mexico City. These are assumptions made for the model to work properly. See Figure 22. In the model, transportation costs from Warehouses to DCs, and from DCs to Customer Zones were also entered accordingly.

PLANTS TO WAREHOUSES -					
PLANT	SHANGAI	MEXICO CITY	LONDON	ATLANTA	MONTREAL
MIAMI	$0.004	$0.150	$0.004	$0.150	$0.060
TORONTO	$0.004	$0.150	$0.004	$0.150	$0.060
TIJUANA	$0.004	$0.150	$0.004	$0.150	$0.150
MUMBAI	$0.150	$0.004	$0.004	$0.004	$0.004
BARCELONA	$0.004	$0.004	$0.060	$0.004	$0.004

Fig. 22– Transportation costs in the Microsoft® Excel model

The transportation distances are very important for the model to obtain the real transportation cost when moving products between facilities. Since the model objective is to minimize total cost, including transportation cost, the distance is a major component of the model. The data that corresponds to transportation distance have been entered individually and have been displayed in the decision model. See Figure 23. For example, the nautical distance for a ship container to transport goods from the port in Miami to the port in Shangai is 8300 miles, whereas truck drivers should drive 600 miles between Miami and Atlanta. These distances are approximations. In the model, transportation distances from Warehouses to DCs, and from DCs to Customer Zones were also entered accordingly.

PLANTS TO WAREHOUSES -					
PLANT	SHANGAI	MEXICO CITY	LONDON	ATLANTA	MONTREAL
MIAMI	8300	1300	4500	600	1400
TORONTO	7200	2000	3600	750	320
TIJUANA	6700	1450	5500	1900	2500
MUMBAI	3200	9800	4500	8500	7500
BARCELONA	6200	5900	720	4600	3700

Fig. 23– Transportation distances in the Microsoft® Excel model

The transportation lead times are also very important for the model to find the fastest routes when moving products between facilities. These lead times are based on the distance of each transportation link, the transportation mode, the average speed travelled by the means of transportation (truck, ship or train), and the transportation efficiency of these means of transportation. The data that corresponds to transportation lead time have been calculated individually and have been displayed in the decision model. See Figure 24. For example, the lead time for a ship container to transport goods from the port in Miami to the port in Shangai is 968.3 hours. The formula is simple: distance divided by the average speed multiplied by the lost efficiency. For the abovementioned example, 8300 miles divided by 15 miles per hour multiplied by 1.75 (lost efficiency due to trucks waiting to unload container, bureaucracy, shipment waiting in docks, etc) returns 968.3 hours. The lead time for a truck to transport goods from Miami to Mexico City is 23.2 hours. Thus, using the same formula, 1300 miles divided by 50 miles per hour multiplied by 1.50 (lost efficiency due to trucks waiting to load container, fill up the tank, rest time, etc) equals 23.2 hours. For last, the lead time for a train to transport goods from Barcelona to London is 21.6 hours. This value was obtained by dividing 720 miles by 70 miles per hour multiplied by 1.25 (lost efficiency due to carts waiting for containers to be placed, railway operations delays, etc.). In the model, transportation lead times from Warehouses to DCs, and from DCs to Customer Zones were also entered accordingly.

PLANTS TO WAREHOUSES -					
PLANT	SHANGAI	MEXICO CITY	LONDON	ATLANTA	MONTREAL
MIAMI	968.3	23.2	525.0	10.7	42.0
TORONTO	840.0	35.7	420.0	13.4	9.6
TIJUANA	781.7	8.0	641.7	33.9	44.6
MUMBAI	57.1	1143.3	525.0	991.7	875.0
BARCELONA	723.3	688.3	21.6	536.7	431.7

Fig. 24– Transportation lead times in the Microsoft® Excel model

The transportation link capacities are also important for the model to be able to find the available routes when moving products between facilities. These capacities are based on the means of transportation (truck, ship or train), only. The data that corresponds to transportation capacity have been entered individually and have been displayed in the decision model. See Figure 25. The capacities of each transportation link were adjusted to reflect the total available transported volume in tons between nodes. From Barcelona to London, it has been estimated a maximum capacity of 5 million tons. Miami-Atlanta has a larger capacity because of the high availability of roadway transportation. In the model, transportation capacities from Warehouses to DCs, and from DCs to Customer Zones were also entered accordingly.

PLANTS TO WAREHOUSES - TRA					
PLANT	SHANGAI	MEXICO CITY	LONDON	ATLANTA	MONTREAL
MIAMI	10,000,000	20,000,000	10,000,000	20,000,000	20,000,000
TORONTO	8,000,000	20,000,000	8,000,000	20,000,000	20,000,000
TIJUANA	5,000,000	20,000,000	5,000,000	20,000,000	20,000,000
MUMBAI	5,000,000	8,000,000	8,000,000	8,000,000	8,000,000
BARCELONA	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000

Fig. 25– Transportation capacities in the Microsoft® Excel model

For this model, the estimated demand for soybeans is near 60 million tons per year. Asia has an estimated demand of 24 million tons per year. It is the highest because of the combined increasing populations of China, India, Indonesia and Russia. Canada has the lowest estimated demand with only 400,000 tons of soybeans per year due to its population followed by the African continent with 800,000 tons per year.

CUSTOMER ZONES	MENU
ZONE	**DEMAND (TONS)**
US-WEST & MEXICO	5,600,000
US-EAST	4,000,000
CANADA	400,000
AMERICAS	5,600,000
EUROPE-EAST	2,400,000
EUROPE-WEST	8,000,000
AFRICA	800,000
MIDDLE EAST	4,000,000
ASIA	24,000,000
OCEANIA	4,000,000
TOTAL GLOBAL DEMAND:	58,800,000

Fig. 26– Demand at the Customer Zones in the Microsoft® Excel model

For this model, ten distributions centers have been selected to handle containers that should be shipped from selected central warehouses. These DCs will handle millions of tons of soybeans to be later distributed to the appropriate customer zones. Handling costs, transfer prices, the fixed costs, duties and tariffs have been adjusted to highlight the

differences in agricultural business in different parts of the world. Infrastructure, wealth and operating costs have been heavily influential in estimating these numbers. See Figure 27. Estimated handling capacities (minimum and maximum) have been entered along with the countries' Freedom Index.

DISTRIBUTION CENTERS
PRINT   NEW DC   MENU

CITY	STATE/ COUNTRY	HANDLING COST/ BU	TRANSFER PRICE/ BU	INVESTMENT/ FIXED COST	DUTIES& TARIFFS	MINIMUM CAPACITY (TONS)	MAXIMUM CAPACITY (TONS)	FREEDOM INDEX
RESTON	U.S.A.	$1.2000	$12.00	$20,000.00	3.00%	2,000,000	8,000,000	80.6
OMAHA	U.S.A.	$1.2000	$12.00	$20,000.00	3.00%	3,000,000	9,000,000	80.6
SAO PAULO	BRAZIL	$1.1000	$11.00	$18,000.00	2.00%	5,000,000	9,000,000	55.9
ALAMOS	MEXICO	$1.1000	$11.00	$10,000.00	3.00%	1,000,000	5,000,000	66.4
FRANKFURT	GERMANY	$1.5000	$15.00	$24,000.00	2.00%	5,000,000	8,000,000	71.2
PORTO	PORTUGAL	$1.4000	$14.00	$22,000.00	2.00%	2,000,000	10,000,000	64.3
HANOI	VIETNAM	$0.9000	$9.00	$9,000.00	5.00%	2,000,000	5,000,000	49.8
SIDNEY	AUSTRALIA	$1.0000	$10.00	$20,000.00	5.00%	5,000,000	9,000,000	82.0
MOSCOW	RUSSIA	$0.9000	$9.00	$15,000.00	4.00%	4,000,000	8,000,000	49.9
CAIRO	EGYPT	$0.8000	$8.00	$11,000.00	6.00%	2,000,000	6,000,000	59.2

Fig. 27– Distribution Center data in the Microsoft® Excel model

For this model, five warehouses have been selected to handle containers that should be shipped from selected plants. The optimal solution should dictate which warehouses will handle millions of tons of soybeans to be later distributed to the appropriate distribution centers. The handling costs, transfer prices, the fixed costs, duties and tariffs have also been revised to depict the differences in how businesses are conducted in different countries. Once again, infrastructure, wealth and operating costs have been heavily influential in estimating these numbers. See Figure 28. Estimated handling capacities (minimum and maximum) have also been entered along with the countries' Freedom Index.

WAREHOUSES   PRINT   NEW WAREHOUSE   MENU

CITY	STATE/ COUNTRY	HANDLING COST/ BU	TRANSFER PRICE/ BU	INVESTMENT/ FIXED COST	DUTIES& TARIFFS	MINIMUM CAPACITY (TONS)	MAXIMUM CAPACITY (TONS)	FREEDOM INDEX
SHANGAI	CHINA	$1.1000	$11.00	$50,000.00	5.00%	10,000,000	20,000,000	52.8
MEXICO CITY	MEXICO	$0.9000	$9.00	$30,000.00	3.00%	5,000,000	15,000,000	66.4
LONDON	UNITED KINGDOM	$1.5000	$15.00	$100,000.00	5.00%	5,000,000	9,000,000	79.5
ATLANTA	U.S.A.	$1.2000	$12.00	$100,000.00	3.00%	10,000,000	20,000,000	80.6
MONTREAL	CANADA	$1.1000	$11.00	$90,000.00	2.00%	7,000,000	13,000,000	80.2

Fig. 28– Warehouse data in the Microsoft® Excel model

A total of five plants have been selected to handle the processing of soybeans that should be shipped later to selected warehouses. As depicted earlier, the optimal solution should dictate which plants will process millions of tons of soybeans to be later distributed to the appropriate warehouses. The processing unit costs, transfer prices, and the fixed costs have been entered according to the differences in the economics of each country. See Figure 29. Estimated processing capacities (minimum and maximum) have also been entered along with the countries' Freedom Index.

PLANTS   PRINT   NEW PLANT   MENU

CITY	STATE/ COUNTRY	UNIT COST/ BU	TRANSFER PRICE/ BU	INVESTMENT/ FIXED COST	MINIMUM CAPACITY (TONS)	MAXIMUM CAPACITY (TONS)	FREEDOM INDEX
MIAMI	U.S.A.	$8.00	$12.00	$1,000,000	5,000,000	17,000,000	80.6
TORONTO	CANADA	$7.00	$11.00	$1,200,000	5,000,000	10,000,000	80.2
TIJUANA	MEXICO	$7.50	$9.00	$500,000	5,000,000	18,000,000	66.4
MUMBAI	INDIA	$6.00	$8.00	$300,000	5,000,000	17,000,000	54.2
BARCELONA	SPAIN	$10.00	$15.00	$1,000,000	3,000,000	15,000,000	69.7

Fig. 29– Plant data in the Microsoft® Excel model

VBA macros have been created, see Appendix B, to make use of all the information entered in the spreadsheet application and run a model that the Premium Solver Platform

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for Excel will be able to select manufacturing sites, warehouses, distribution centers and retail facilities, and then will assume these selected sites fixed for a subsequent re-optimization. The model can identify if existing facility locations and logistics structure are optimal for the company to minimize operational costs. The Premium Solver Platform for Excel that has been used for the Global Supply Chain Network Model can analyze and interpret a model when information is entered properly as depicted in Figure 18 (chapter 3). The VBA macro has been created to automatically run the Solver application. Otherwise, the user would be required to run the Premium Solver out of the menu bar. See Figure 30.
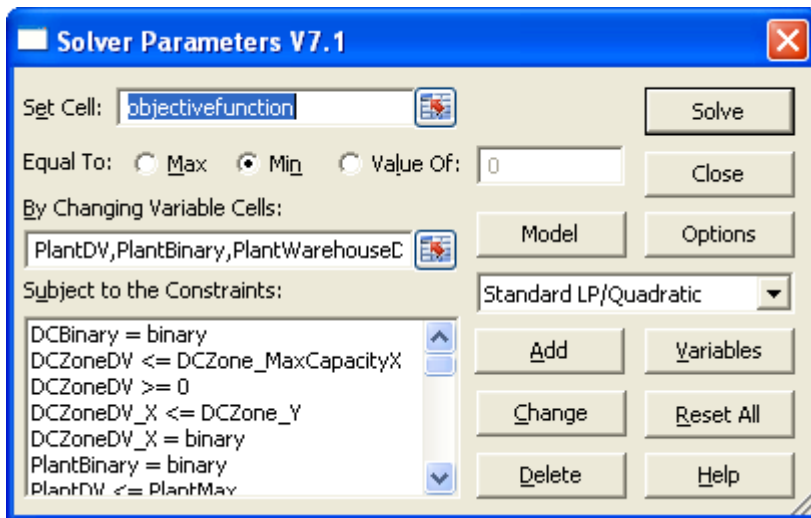
Fig. 30– Premium Solver Platform in Microsoft® Excel

After pressing the Solve button, the Premium Solver Platform for Excel starts looking for the optimal solution which will minimize all costs involved. The VBA macro should ask the user to select the plants, warehouses, distribution centers and customer zones that will be part of the model. One may select just a few, or all of them, by holding the control key down (Ctrl) and picking the preferred ones or by dragging the left mouse button. A few messages are displayed at the Status Bar after the Solver is evoked. First message is

"Analyzing Solver Model," followed by "Parsing Problem Function," "Fast Problem Setup," "Subproblem," "Incumbent," and "Trial Solution." It may stay under one message for a couple of seconds and then proceed. It takes approximately one minute to obtain the optimal solution. See Figure 31.
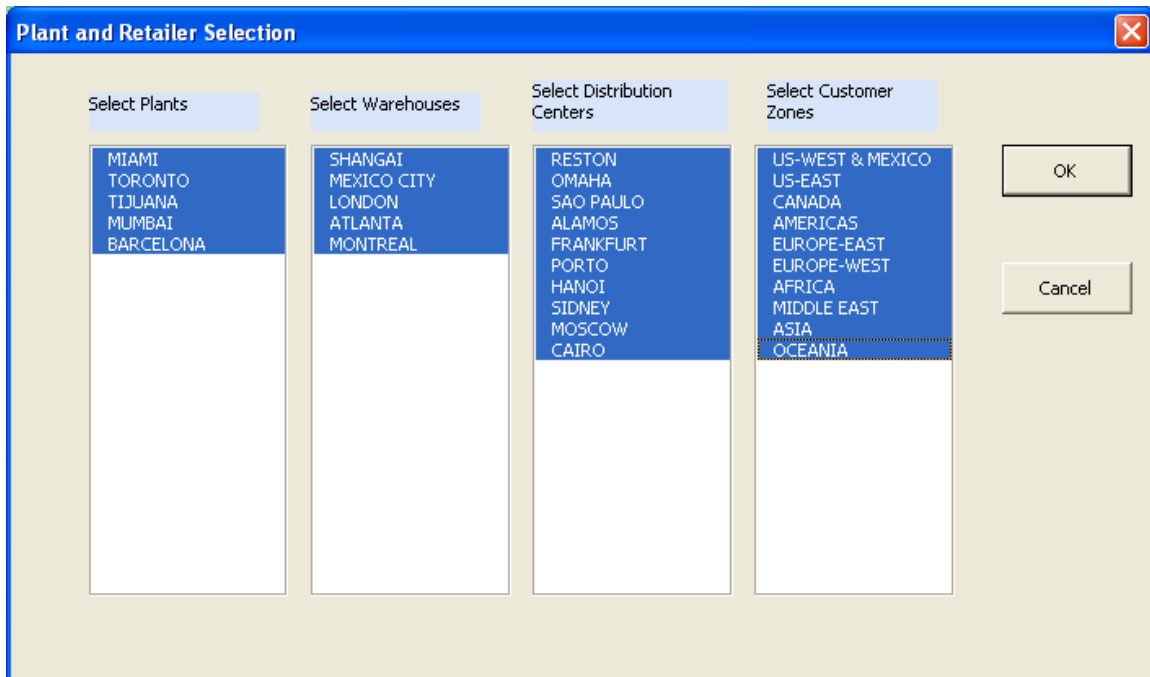
Fig. 31– VBA macro screen to select Facilities in the Microsoft® Excel model

The charts displayed in the Microsoft® Excel application, as depicted below, show the optimal solution in terms of the annual volume in tons to be transported between locations. See Figures 32, 33 and 34.

PLANT TO WAREHOUSE

	SHANGAI	MEXICO CITY	LONDON	ATLANTA	MONTREAL
■ MIAMI	5000000	0	0	7800000	1000000
□ TORONTO	0	0	0	0	10000000
□ TIJUANA	5000000	8000000	5000000	0	0
□ MUMBAI	0	7000000	0	8000000	2000000
■ BARCELONA	0	0	0	0	0

Fig. 32– Optimal Plant to Warehouse Solution in the Microsoft® Excel model

WAREHOUSE TO DISTRIBUTION CENTERS

	RESTON	OMAHA	SAO PAULO	ALAMOS	FRANKFURT	PORTO	HANOI	SIDNEY	MOSCOW	CAIRO
■ SHANGAI	0	8800000	0	0	0	0	0	0	1200000	0
□ MEXICO CITY	0	0	0	5000000	0	0	0	5000000	5000000	0
□ LONDON	5000000	0	0	0	0	0	0	0	0	0
□ ATLANTA	0	0	5800000	0	0	10000000	0	0	0	0
■ MONTREAL	0	0	3200000	0	8000000	0	0	0	1800000	0

Fig. 33– Optimal Warehouse DCs Solution in the Microsoft® Excel model

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DISTRIBUTION CENTERS TO CUSTOMER ZONES

	US-WEST & MEXICO	US-EAST	CANADA	AMERICAS	EUROPE-EAST	EUROPE-WEST	AFRICA	MIDDLE EAST	ASIA	OCEANIA
■ RESTON	0	0	0	0	2400000	1600000	0	0	1000000	0
□ OMAHA	0	0	0	0	0	3000000	0	0	3000000	2800000
■ SAO PAULO	3000000	3000000	0	1800000	0	400000	800000	0	0	0
□ ALAMOS	0	0	0	3800000	0	0	0	0	0	1200000
■ FRANKFURT	1600000	0	0	0	0	0	0	1400000	5000000	0
□ PORTO	1000000	1000000	400000	0	0	0	0	2600000	5000000	0
■ HANOI	0	0	0	0	0	0	0	0	0	0
□ SIDNEY	0	0	0	0	0	0	0	0	5000000	0
■ MOSCOW	0	0	0	0	0	3000000	0	0	5000000	0
■ CAIRO	0	0	0	0	0	0	0	0	0	0

Fig. 34– Optimal DCs to Customer Zones Solution in the Microsoft® Excel model

To better display the result of this first optimization process, tables are shown below. In Table 1, it stands to reason that the Miami plant does not deliver all the available volume capacity to the Atlanta warehouse. By the same token, the Tijuana plant does not attend all the needs of the Mexico City warehouse. Link capacities for both itineraries are 20 million tons, but transportation costs by roadway make it the transport of goods by trucks not viable even for short distances. Mumbai, India, will complement the demands in Atlanta and Mexico City because of the viable cost of transporting goods by sea, its inexpensive plant operating costs and handling costs, and its low transfer price. The Barcelona plant does not seem workable for this model. In Chapter 5, sensitivity analysis will transform this model into a more realistic one when roadway transportation seems more feasible in a context of time and agility. For now, we must recognize that this model has done its work in minimizing the total costs of processing and delivering the goods to the right destinations.

Table 1– Optimal Plant to Warehouse Solution in the Microsoft® Excel model

Plant	SHANGAI	MEXICO CITY	LONDON	ATLANTA	MONTREAL
MIAMI	5000000	0	0	7800000	1000000
TORONTO	0	0	0	0	10000000
TIJUANA	5000000	8000000	5000000	0	0
MUMBAI	0	7000000	0	8000000	2000000
BARCELONA	0	0	0	0	0

In Table 2, there is another consideration that makes this first optimization process not very reasonable. The warehouse in Atlanta could have taken care of most of the maximum holding capacity (17 million tons) of the distribution centers Reston, VA and Omaha, NE. In the contrary, these two distribution centers received the containers from London, England and Shanghai, China, respectively. However, the warehouse in Mexico City provides the maximum number of tons allowed in the distribution center in Alamos, Mexico. Thus, trucks have been used to transport these goods between the two locations. We will assure in the coming chapter that costs alone cannot provide the "best" alternative use of different modes of transportation.

Table 2– Optimal Warehouse to DCs Solution in the Microsoft® Excel model

Warehouse	RESTON	OMAHA	SAO PAULO	ALAMOS	FRANKFURT	PORTO	HANOI	SIDNEY	MOSCOW	CAIRO
SHANGAI	0	8600000	0	0	0	0	0	0	1200000	0
MEXICO CITY	0	0	0	5000000	0	0	0	5000000	5000000	0
LONDON	5000000	0	0	0	0	0	0	0	0	0
ATLANTA	0	0	5800000	0	0	10000000	0	0	0	0
MONTREAL	0	0	3200000	0	8000000	0	0	0	1800000	0

In Table 3, there are several considerations that make this first optimization process not very realistic. The distribution centers in Reston and Omaha could have taken care of all the maximum holding capacity (10 million tons) of the following customer zones: US-West and Mexico, US-East and Canada. In the contrary, these three customer zones received the

containers from Sao Paulo, Brazil, Frankfurt, Germany and Porto, Portugal. London, England and Shangai, China, respectively. Also, Porto and Frankfurt are not supplying the market in Eastern Europe. Moscow supplies only 3 million tons to Western Europe out of total demand of 8 million tons. The distribution centers in Hanoi, Vietnam and Cairo, Egypt must not continue operation or should not exist. Once again, in this model, optimal solution does not indicate the "best" alternative use of different modes of transportation.

Table 3– Optimal DCs to Customer Zones Solution in the Microsoft® Excel model

DCs	US-WEST & MEXICO	US-EAST	CANADA	AMERICAS	EUROPE-EAST	EUROPE-WEST	AFRICA	MIDDLE EAST	ASIA	OCEANIA
RESTON	0	0	0	0	2400000	1600000	0	0	1000000	0
OMAHA	0	0	0	0	0	3000000	0	0	3000000	2800000
SAO PAULO	3000000	3000000	0	1800000	0	400000	800000	0	0	0
ALAMOS	0	0	0	3800000	0	0	0	0	0	1200000
FRANKFURT	1600000	0	0	0	0	0	0	1400000	5000000	0
PORTO	1000000	1000000	400000	0	0	0	0	2600000	5000000	0
HANOI	0	0	0	0	0	0	0	0	0	0
SIDNEY	0	0	0	0	0	0	0	0	5000000	0
MOSCOW	0	0	0	0	0	3000000	0	0	5000000	0
CAIRO	0	0	0	0	0	0	0	0	0	0

The Premium Solver Platform for Excel® that I used for the Global Supply Chain Network Model has many options for solving mixed-integer models. The results will vary according to the options that were selected during the layout of the model. Thus, different optimal solutions can derive from this Premium Solver Platform. More importantly is the fact that an optimal solution was found without restrictions which indicates that this is a reliable model for global sourcing selection. This first optimization assumed that locations were not fixed and could be changed according to the model feasibility. Next, the model will assume fixed locations and/or the significance of freedom index in locating the facilities that should minimize total cost. Then, sensitivity analysis will be used to make sure that the

model is realistic regarding the use of trucks and railroads, when they are bound to be a better transportation solution. So far, the model seems to be reliable.

CHAPTER 5 - SOLUTIONS AND SENSITIVITY

The optimal solution found in the previous chapter depended on a combination of inputs that were entered through some research effort without the use of an existing firm. The soybean was selected and the various prices and costs associated with the processing, transfer and hauling of this major global commodity were collected via the Internet and phone calls. The Excel mixed-integer model was able by means of an LP optimization process to select manufacturing sites, warehouses, distribution centers and retail facilities that minimized total costs. In this chapter, I will make changes in the model parameters and later in some of its data to assure that it will serve as a great tool for global supply chain strategic planning when assuming potential manufacturing sites, warehouse facilities and distribution centers. The total values of all the components of the objective function (first optimal solution) are displayed in Figure 35 so as to verify how the changes planned to take effect into the model later on.

Summary

Total Cost of Production	$15,345,588,235
Plant Fixed Costs	$3,519,000
Total Handling Costs	$4,978,676,471
Total Freedom Index Value	0.00
Total Transportation Costs	$4,949,700,000
Total Tariffs and Duties	$13,587,500,000
Lead Time Values	59,992,183
Total Optimal Cost	38,924,975,889

Fig. 35– Summary of all Objective Function Component Values

Because the global distribution network deals with political, social, economic and trade instability, the Heritage Foundation's Economic Freedom Index will be used now. As a

reminder, Spain was not considered too risky and Barcelona was not considered part of the optimal solution when the Freedom Index was not part of the model. The distribution center in Vietnam was also not part of the solution, even though it showed a risky business environment. Changing the Freedom Index in the Parameters and solving the model, we came up with a new solution. The new solution turned out to be the same as the previous optimal solution, except for the objective function that added 87,333,900 to its total value.

Summary

Total Cost of Production	$15,345,588,235
Plant Fixed Costs	$3,519,000
Total Handling Costs	$4,978,676,471
Total Freedom Index Value	87,333,900.00
Total Transportation Costs	$4,949,700,000
Total Tariffs and Duties	$13,587,500,000
Lead Time Values	59,992,183
Total Optimal Cost	39,012,309,789

Fig. 36– Summary of all Objective Function Component Values – Freedom Index

In Figure 36, the model assumes the Freedom Index (FREEDOM INDEX = YES) to be a number no greater than 100. If we augment these numbers by 10-fold to increase the impact of the Freedom Index value in the model and re-run the model, the decision variables will change very little. Now, Shangai receives more goods, and Montreal provides all the goods to Moscow. See Tables 4 and 5.

Table 4– Optimal Plant to Warehouse Solution – Adjusted Freedom Index 10-Fold

Plant	SHANGAI	MEXICO CITY	LONDON	ATLANTA	MONTREAL
MIAMI	6800000	0	0	6000000	1000000
TORONTO	0	0	0	0	10000000
TIJUANA	5000000	8000000	5000000	0	0
MUMBAI	0	7000000	0	8000000	2000000
BARCELONA	0	0	0	0	0

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Table 5– Optimal Warehouse to DCs Solution – Adjusted Freedom Index 10-Fold

Warehouse	RESTON	OMAHA	SAO PAULO	ALAMOS	FRANKFURT	PORTO	HANOI	SIDNEY	MOSCOW	CAIRO
SHANGAI	600000	8000000	0	0	3000000	0	0	0	0	0
MEXICO CITY	0	0	0	5000000	5000000	0	0	5000000	0	0
LONDON	5000000	0	0	0	0	0	0	0	0	0
ATLANTA	0	0	4000000	0	0	10000000	0	0	0	0
MONTREAL	0	0	5000000	0	0	0	0	0	8000000	0

If we continue to augment the Freedom Index value by 100-fold or more and re-run the model, the decision variables will also change very little. The warehouse in London must be shut down and very little route rearrangements will occur because of that. In fact, England offers a good environment for business, but the investment to open or run a facility in that country is very expensive.

First, we assumed that the network was not fixed (FIXED NETWORK = NO). Now, we will re-optimize the model with fixed network, considering all plant sites to be selected as well as manufacturing or distribution sites (FIXED NETWORK = YES). For this optimization, the Freedom Index is not part of the solution (FREEDOM INDEX = NO).

Table 6– Optimal Plant to Warehouse Solution – Fixed Network

Plant	SHANGAI	MEXICO CITY	LONDON	ATLANTA	MONTREAL
MIAMI	5000000	0	0	5800000	0
TORONTO	0	0	0	0	10000000
TIJUANA	5000000	8000000	5000000	0	0
MUMBAI	0	7000000	0	8000000	2000000
BARCELONA	0	0	0	2000000	1000000

In Table 6, the optimal solution includes Barcelona, which is now a fixed (existing) plant and distributes goods to two major warehouses in Atlanta and Montreal. The plant in Miami is now short in 3 million tons of soybeans because of the inclusion of the plant in Barcelona due to its higher unit cost and transfer price.

Table 7– Optimal Warehouse to DCs Solution – Fixed Network

Warehouse	RESTON	OMAHA	SAO PAULO	ALAMOS	FRANKFURT	PORTO	HANOI	SIDNEY	MOSCOW	CAIRO
SHANGAI	0	7000000	0	3000000	0	0	0	0	0	0
MEXICO CITY	0	0	0	1600000	0	0	2000000	5000000	4400000	2000000
LONDON	5000000	0	0	0	0	0	0	0	0	0
ATLANTA	0	0	9000000	0	50000	6750000	0	0	0	0
MONTREAL	0	0	0	0	7950000	3250000	0	0	1800000	0

In Table 7, the optimal solution includes Hanoi and Cairo, which are now fixed (existing) distribution centers and receive goods from the same warehouse in Mexico City. The warehouse in Mexico City took deliveries to more distribution centers now, also Moscow, because of its lower handling cost, transfer price and facility fixed cost. The warehouses of Atlanta and Montreal suffered little changes in deliveries to other distribution centers, but they are not as significant as the ones in Mexico City.

Table 8– Optimal DCs to Customer Zones Solution – Fixed Network

DCs	US-WEST & MEXICO	US-EAST	CANADA	AMERICAS	EUROPE-EAST	EUROPE-WEST	AFRICA	MIDDLE EAST	ASIA	OCEANIA
RESTON	0	0	0	0	1400000	1000000	0	0	2600000	0
OMAHA	0	0	0	0	0	3000000	0	0	3000000	1000000
SAO PAULO	3000000	3000000	0	3000000	0	0	0	0	0	0
ALAMOS	0	0	0	2600000	0	0	0	0	0	2000000
FRANKFURT	1600000	0	0	0	0	0	800000	600000	5000000	0
PORTO	1000000	1000000	400000	0	0	0	0	3400000	4200000	0
HANOI	0	0	0	0	0	1000000	0	0	0	1000000
SIDNEY	0	0	0	0	0	0	0	0	5000000	0
MOSCOW	0	0	0	0	0	3000000	0	0	3200000	0
CAIRO	0	0	0	0	1000000	0	0	0	1000000	0

In Table 8, the optimal solution includes Hanoi and Cairo as distribution centers which makes the model slightly adjust to new movements of containers around the globe. The DC in Omaha decreases delivery to Oceania, allowing Hanoi to deliver 1 million tons to that continent. Adjustments have also been made by distribution centers to Asia to let the DC in Cairo to deliver 1 million tons to that continent. Due to the inclusion of all facilities, the DC in Sao Paulo was also responsible to meet the demands of soybeans in Western Europe and Africa. The distribution centers of Omaha and Moscow took less delivery of

soybeans to permit Hanoi and Cairo to enter the global network. In a nutshell, by maintaining all the pre-selected facilities, the global supply chain network was not better off than the non-fixed facility optimal solution.

The transportation data were crucial for this model to be feasible and capable of obtaining meaningful results. The data that correspond to transportation links were entered individually and it may have caused some of these facilities to overreact during a change of parameters. The main transportation categories, distance, cost, capacity and lead time, were heavily weighed by the model along with handling costs, transfer prices and investment cost on the facilities. The fixed-network model improved the following network components: handling costs and transportation costs. When comparing Figure 35 with Figure 37, we observed that the fixed-network was worse off in the following components of the objective function: cost of production, plant fixed costs, tariffs and duties and lead time.

Summary	
Total Cost of Production	$15,566,176,471
Plant Fixed Costs	$4,539,000
Total Handling Costs	$4,948,529,412
Total Freedom Index Value	0.00
Total Transportation Costs	$4,720,700,000
Total Tariffs and Duties	$13,938,235,294
Lead Time Values	70,481,954
Total Optimal Cost	39,248,662,131

Fig. 37– Summary of all Objective Function Component Values – Fixed-Network

The lesson learned from allowing the model to be subject to fixed facilities was that there is a trade-off between logistics costs (handling and transportation) and processing related costs (facility and production). One cannot overlook these two network focus areas.

The transportation distances and lead times are very important for the model to obtain the real transportation cost when moving products between facilities as fast as possible. These lead times that are based on the distance of each transportation link, the transportation mode, the average speed travelled by the means of transportation (truck, ship or train), and the transportation efficiency of these means of transportation were not as valuable as the transportation costs alone. For example, it sounds realistic to transport goods from Atlanta, Georgia to Reston, Virginia by truck. The original model solution did not take into account that by truck these containers will get to the final location much faster. However, the cost of $0.15 per ton/mile makes it difficult for the mixed-integer programming to select the roadway as the least costly because the model is trying to minimize total costs. Thus, it stands to reason that we must change some of these values to make this model more prone to a more practical optimal solution. The value of choice is the cost of transportation between nodes. By changing the costs of all links that truck transportation would make more sense to zero, it will force the mixed-integer programming to adopt these roadways for hauling these tonnages of processed soy.

PLANT	SHANGAI	MEXICO CITY	LONDON	ATLANTA	MONTREAL
MIAMI	$0.004	$0.000	$0.004	$0.000	$0.060
TORONTO	$0.004	$0.000	$0.004	$0.000	$0.060
TIJUANA	$0.004	$0.000	$0.004	$0.000	$0.000
MUMBAI	$0.000	$0.004	$0.004	$0.004	$0.004
BARCELONA	$0.004	$0.004	$0.060	$0.004	$0.004

Fig. 38– Transportation Costs assuming Trucks over Other Means – Plant to WR

WAREHOUSE	RESTON	OMAHA	SAO PAULO	ALAMOS	FRANKFURT	PORTO	HANOI	SIDNEY	MOSCOW	CAIRO
SHANGAI	$0.004	$0.004	$0.004	$0.004	$0.004	$0.004	$0.000	$0.004	$0.004	$0.004
MEXICO CITY	$0.000	$0.000	$0.004	$0.000	$0.004	$0.004	$0.004	$0.004	$0.004	$0.004
LONDON	$0.004	$0.004	$0.004	$0.004	$0.060	$0.060	$0.004	$0.004	$0.004	$0.004
ATLANTA	$0.000	$0.000	$0.004	$0.000	$0.004	$0.004	$0.004	$0.004	$0.004	$0.004
MONTREAL	$0.000	$0.000	$0.004	$0.000	$0.004	$0.004	$0.004	$0.004	$0.004	$0.004

Fig. 39– Transportation Costs assuming Trucks over Other Means – WR to DC

WAREHOUSE	US-WEST & MEXICO	US-EAST	CANADA	AMERICAS	EUROPE-EAST	EUROPE-WEST	AFRICA	MIDDLE EAST	ASIA	OCEANIA
RESTON	$0.000	$0.000	$0.000	$0.004	$0.004	$0.004	$0.004	$0.004	$0.004	$0.004
OMAHA	$0.000	$0.000	$0.000	$0.004	$0.004	$0.004	$0.004	$0.004	$0.004	$0.004
SAO PAULO	$0.004	$0.004	$0.004	$0.004	$0.004	$0.004	$0.004	$0.004	$0.004	$0.004
ALAMOS	$0.000	$0.000	$0.000	$0.004	$0.004	$0.004	$0.004	$0.004	$0.004	$0.004
FRANKFURT	$0.004	$0.004	$0.004	$0.004	$0.060	$0.060	$0.004	$0.004	$0.004	$0.004
PORTO	$0.004	$0.004	$0.004	$0.004	$0.060	$0.060	$0.000	$0.004	$0.004	$0.004
HANOI	$0.004	$0.004	$0.004	$0.004	$0.004	$0.004	$0.004	$0.004	$0.150	$0.004
SIDNEY	$0.004	$0.004	$0.004	$0.004	$0.004	$0.004	$0.004	$0.004	$0.004	$0.060
MOSCOW	$0.004	$0.004	$0.004	$0.004	$0.060	$0.004	$0.004	$0.004	$0.004	$0.004
CAIRO	$0.004	$0.004	$0.004	$0.004	$0.004	$0.000	$0.000	$0.000	$0.004	$0.004

Fig. 40 – Transportation Costs assuming Trucks over Other Means – DC to CZone

In Figures 38, 39 and 40, we show that we waived the hauling cost of millions of tons of soybeans to be distributed from plants to warehouses to distribution centers to the appropriate customer zones. Handling costs, transfer prices, the fixed costs, duties and tariffs have not been changed. Even though infrastructure, wealth and operating costs have been heavily influential in how the mixed-integer programming selects the optimal solution, we will see that waiving these roadway costs will have a great impact in the efficiency of the global supply chain network. See Figure 41.

PLANT TO WAREHOUSE

	SHANGAI	MEXICO CITY	LONDON	ATLANTA	MONTREAL
■ MIAMI	0	13800000	0	0	0
□ TORONTO	800000	0	0	9200000	0
□ TIJUANA	5000000	1200000	0	6800000	5000000
□ MUMBAI	5000000	0	0	4000000	8000000
■ BARCELONA	0	0	0	0	0

Fig. 41– Optimal Plant to Warehouse Solution – Zero Cost for Trucks

For this model, only four plants (Barcelona is out) have been selected to process the soybean and ship the containers to the various warehouses. The optimal solution dictated that London should not be selected as a warehouse for handling these millions of tons of soybeans to be later distributed to the appropriate distribution centers. Tijuana became a major plant in the network with distribution to all selected warehouses due to its low facility fixed cost. Now, transportation by truck becomes a major aspect of this network with that being used in North America and Asia.

WAREHOUSE TO DISTRIBUTION CENTERS

	RESTON	OMAHA	SAO PAULO	ALAMOS	FRANKFURT	PORTO	HANOI	SIDNEY	MOSCOW	CAIRO
■ SHANGAI	0	0	0	0	1000000	0	2000000	0	7800000	0
□ MEXICO CITY	0	9000000	1000000	5000000	0	0	0	0	0	0
□ LONDON	0	0	0	0	0	0	0	0	0	0
□ ATLANTA	2000000	0	8000000	0	0	10000000	0	0	0	0
■ MONTREAL	6000000	0	0	0	7000000	0	0	0	0	0
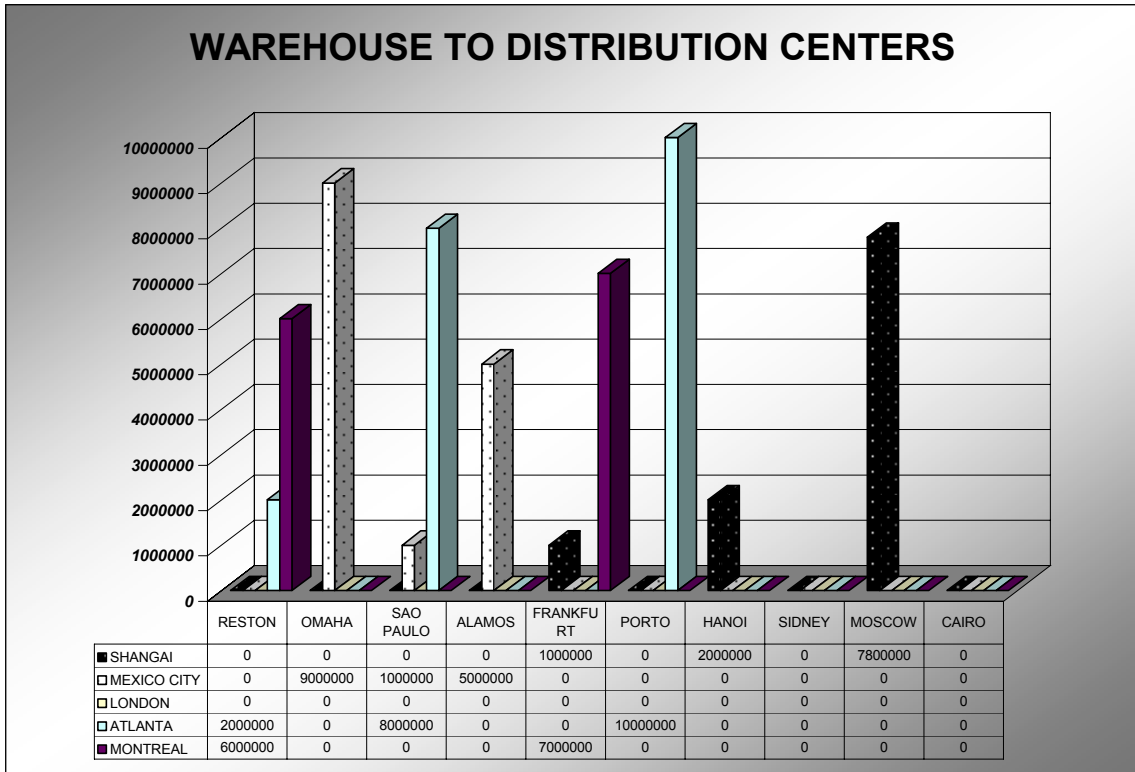
Fig. 42– Optimal Warehouse to DCs Solution – Zero Cost for Trucks

In Figure 42, the warehouse to DC solution seems a lot more realistic than the original model. For example, the warehouse in Mexico City transports containers to Omaha, Sao Paulo and Alamos as opposed Sydney and Moscow. The warehouse in Shanghai continues to deliver processed soy to Moscow in addition to Frankfurt and Hanoi. The warehouses in Atlanta and Montreal now ship products to Reston, Virginia. According to the new Premium Solver Platform solution, Sydney and Cairo should not be part of this network. Hanoi has been selected in place of Sydney. The reason being is that Sydney has higher handling costs, transfer price and facility fixed cost which have not been captured by the model when trucks were in complete disadvantage.

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DISTRIBUTION CENTERS TO CUSTOMER ZONES

	US-WEST & MEXICO	US-EAST	CANADA	AMERICAS	EUROPE-EAST	EUROPE-WEST	AFRICA	MIDDLE EAST	ASIA	OCEANIA
■ RESTON	1200000	800000	0	0	0	3000000	0	0	3000000	0
□ OMAHA	4400000	0	0	0	0	1600000	0	0	3000000	0
■ SAO PAULO	0	0	0	3000000	2400000	600000	0	0	0	3000000
□ ALAMOS	0	1400000	0	1600000	0	0	0	0	2000000	0
■ FRANKFURT	0	800000	0	0	0	0	0	2200000	5000000	0
□ PORTO	0	1000000	400000	1000000	0	0	800000	1800000	5000000	0
■ HANOI	0	0	0	0	0	1000000	0	0	0	1000000
□ SIDNEY	0	0	0	0	0	0	0	0	0	0
■ MOSCOW	0	0	0	0	0	1800000	0	0	6000000	0
■ CAIRO	0	0	0	0	0	0	0	0	0	0

Fig. 43– Optimal DCs to Customer Zone Solution – Zero Cost for Trucks

In Figure 43, we see several changes that took place from original model. Trucks have now been used to transport the processed soy from the two distribution centers in the U.S. (Reston and Omaha) to the two regions in the same continent (US-WEST & MEXICO. and US-EAST). However, other three DCs also transport soy to the Eastern U.S., including Alamos, Frankfurt and Porto. To Oceania, with Sydney being selected out, Sao Paulo and Hanoi became responsible to meet demand. Asia suffered some changes in delivery sources, but it is mainly because of its high demand and the various concurrent sources of low handling costs. Because Porto is now delivering soy to Mexico, the demand in the Americas has been met by only two sources, Sao Paulo and Alamos. Sao Paulo, in turn, has delivered more of its soy to Eastern Europe rather than to the Americas due to Alamos great sourcing.

Africa's major source is now Porto, as opposed to Sao Paulo. These changes are a result of this new mixed-integer global supply chain model to optimize its operations taking into account all the logistics, processing, trading and maintenance costs.

In summary, waiving truck costs brought about a series of benefits to the global supply chain model. Plant fixed costs were reduced due to the exclusion of the warehouse in London and the distribution center in Sydney. Handling costs were slightly reduced due to the use of some low handling cost facilities such as Alamos and Moscow. Tariffs and duties were also reduced due to the exclusion of high import tax countries/continents such as England and Oceania. Lead times also came down because of the use of trucks within the same continent. See Figure 44.

Summary

Total Cost of Production	$15,345,588,235
Plant Fixed Costs	$3,408,000
Total Handling Costs	$4,937,500,000
Total Freedom Index Value	0.00
Total Transportation Costs	$2,093,808,000
Total Tariffs and Duties	$12,965,441,176
Lead Time Values	46,897,200
Total Optimal Cost	35,392,642,612

Fig. 44– Summary of all Objective Function Component Values – Zero Cost for Trucks

The breakeven point that offers advantage to the use of trucks rather than railroads and sea freight should be between $0.004 and $0.06 per ton/mile. This model proves to be a good network model for global supply chain optimization.

CONCLUSION

The objective of my thesis was to implement a strategic planning model using Microsoft Excel Solver (Premium Simplex) for the selection of worldwide manufacturing sites, distribution sites, transportation nodes and flow of products between nodes. The mixed-integer model selected manufacturing sites and then assumed these selected sites fixed for a subsequent re-optimization. Also, a supplemental mixed-integer model was used to help select all related sites by means of the Economic Freedom Index. Sensitivity analysis was presented subsequently.

This work was challenging for a variety of reasons. It assumed that products could be shipped to all countries in the world. The model had the following features: deterministic in nature, single product, three stages of the supply chain, single period, linear production and transportation costs, and cost minimization. The customer zones were pre-selected regions of the world with deterministic demand. Any shipment was allowed from plants to warehouses, from warehouses to distribution centers, and from distribution centers to customer zones. Excel was to be used as a computer application for global supply chain optimization, including charts, data tables and pivot charts. The inclusion of an economic freedom index as a coefficient for decision variable selection has been tested.

I followed a systematic approach to run the model and accomplished these various tasks: developed a mixed-integer model formulation for global supply chain strategic planning in Excel assuming potential manufacturing sites, warehouse facilities and distribution centers; modified the mixed-integer model to assume selected, optimal manufacturing sites as fixed locations for the global supply chain strategic planning;

determined and analyzed the optimal solution strategy to gain an understanding of the movement of goods across the five continents; redefined the mixed-integer model formulation to account for uncertainties in countries' economic freedom assuming potential manufacturing sites, warehouse facilities and distribution centers; analyzed the results and compared with the original model; and performed sensitivity analysis to improve supply chain strategic gains when using single source suppliers.

This is a successful example of how global supply chain models work and how to redesign manufacturing and distribution strategy. For instance, Sydney might not be a good sourcing place due to its high handling costs and fixed costs, in turn a company must find a facility in adjacent countries that can provide the means for reducing total operating and fixed costs. A country risk index has potential to help select places where trade is free and bureaucracy is insignificant, but the Economic Freedom Index from The Heritage Foundation does seem to be the best option. This model is a very small mixed-integer linear program that shows potential for further studies and increments. For example, it can be augmented to recommend which mean of transportation should be used for each size of shipment between locations, to reduce the sourcing base, and restructure the distribution network and manufacturing sites. This model could have been implemented at a global firm to prove its usefulness. Thus, more studies are necessary to make sure that the use of this global supply chain optimization model to redistribute a worldwide manufacturing and distribution networks is valid.

APPENDICES

APPENDIX A - NOTATION

p = plants

w = warehouses

d = distribution centers

z = customer zones

Q_p = rate of production by plant p.

Q_{pw} = rate of flow of the product from plant p to warehouse w.

Q_{wd} = rate of flow of the product from warehouse w to distribution center d.

Q_{dz} = rate of flow of the product from distribution center d to customer zone z.

Y_p = 1, if the plant p is to be established; 0, otherwise.

Y_w = 1, if the warehouse w is to be established; 0, otherwise.

Y_d = 1, if the distribution center d is to be established; 0, otherwise.

X_{pw} = 1, if plant p is to ship to warehouse w; 0, otherwise.

X_{wd} = 1, if warehouse w is to ship to distribution center d; 0, otherwise.

X_{dz} = 1, if distribution center d is to ship to customer zone z; 0, otherwise.

C_p = unit production cost of plant p.

P_p^{max} = maximum production capacity of plant p.

P_p^{min} = minimum production capacity of plant p.

W_w^{max} = maximum material handling capacity at warehouse w.

W_w^{min} = minimum material handling capacity at warehouse w.

DC_d^{max} = maximum material handling capacity at distribution center d.

DC_d^{min} = minimum material handling capacity at distribution center d.

I_p = annualized fixed cost of establishing or maintaining a plant p.

I_w = annualized fixed cost of establishing or maintaining a warehouse w.

I_d = annualized fixed cost of establishing or maintaining a distribution center d.

C_{pw} = transportation cost from plant p to warehouse w.

C_{wd} = transportation cost from warehouse w to distribution center d.

C_{dz} = transportation cost from distribution center d to customer zone z.

L_{pw}^{max} = maximum rate of flow from plant p to warehouse w.

L_{wd}^{max} = maximum rate of flow from warehouse w to distribution center d.

L_{dz}^{max} = maximum rate of flow from distribution center d to customer zone z.

H_w = unit handling cost at warehouse w.

H_d = unit handling cost at distribution center d.

T_w = tariffs as a % of the total price of materials shipped to warehouse w.

T_d = tariffs as a % of the total price of materials shipped to distribution center d.

TP_p = transfer price of the product at plant p.

TP_w = transfer price of the product at warehouse w.

TP_d = transfer price of the product at distribution center d.

LT_{pw} = transportation lead time from plant p to warehouse w.

LT_{wd} = transportation lead time from warehouse w to distribution center d.

LT_{dz} = transportation lead time from distribution center d to customer zone z.

D_z = demand for the product in customer zone z.

F_p = the inverse of the freedom index of country where plant p resides.

F_w = the inverse of the freedom index of country where warehouse w resides.

F_d = the inverse of the freedom index of country where distribution center d resides.

DT_{pw} = distance in miles between plant p and warehouse w.

DT_{wd} = distance in miles between warehouse w and distribution center d.

DT_{dz} = distance in miles between distribution center d and customer zone z.

AF^T = adjustment factor for tariffs and duties (default $=10$)

AF^{LT} = adjustment factor for lead time (default $=2400$)

TON = conversion factor to tons in the transfer price.

```vba
Option Explicit
Option Base 1

Public nPlants As Integer, nWarehouses As Integer
Public nDCs As Integer, nZones As Integer

Public plantList() As String, warehouseList() As String
Public DCList() As String, ZoneList() As String

Public isSelectedPlant() As Boolean, isSelectedWarehouse() As Boolean
Public isSelectedDC() As Boolean, isSelectedZone() As Boolean

Public nResourcePlants As Integer
Public nResourcewarehouses As Integer
Public nResourceDCs As Integer
Public nResourceZones As Integer

Public resourceplantList(20, 10) As Variant
Public resourcewarehouseList(20, 10) As Variant
Public resourceDCList(20, 10) As Variant
Public resourcezoneList(20, 10) As Variant

'Public nSelectedPlants As Integer, nSelectedWarehouses As Integer
'Public nSelectedDCs As Integer, nSelectedZones As Integer

'Public selectedPlant() As String, selectedWarehouse() As String
'Public selectedDC() As String, selectedZones() As String
' Instantiate connection and recordset objects for later use.
'Dim cn As New ADODB.Connection, rs As New ADODB.Recordset

Sub MainSupplyChainMix()
' This sub runs when the user clicks on the button on the Explanation sheet.
Call GetPlants
Call Getwarehouses
Call GetDCs
Call GetZones
Call GetPlantResources
Call GetwarehouseResources
Call GetDCResources
Call GetZoneResources
Sheets("Menu").Select
frmInputs.Show
Application.ScreenUpdating = False
Call SetupModel
Call Charts
'    Call CreateReport
End Sub

Sub GetPlants()
' This sub finds the number of plants and their corresponding data.
Worksheets("PLANTS").Select
With Range("PlantAnchor")
If .Offset(1, 0).Value = "" Then
MsgBox "First Plant has not been entered !!!", vbExclamation, "Infeasible"
End
Else
nPlants = Range(.Offset(1, 0), .End(xlDown)).Count
ReDim plantList(nPlants)
ReDim isSelectedPlant(nPlants)
Dim i As Integer
For i = 1 To nPlants
plantList(i) = .Offset(i, 0)
Next
```

```
End If
End With


'    Worksheets("Sheet1").Activate
'    With Range("Anchor")
'    Dim w As Integer
'    For w = 1 To nPlants
'        .Offset(w, 1).Value = plantList(w)
'    Next
'    End With

End Sub
Sub Getwarehouses()
' This sub finds the number of warehouses and their corresponding data.
Worksheets("WAREHOUSES").Select
With Range("WarehouseAnchor")
If .Offset(1, 0).Value = "" Then
MsgBox "First Warehouse has not been entered !!!", vbExclamation, "Infeasible"
End
Else
nWarehouses = Range(.Offset(1, 0), .End(xlDown)).Count
ReDim warehouseList(nWarehouses)
ReDim isSelectedWarehouse(nWarehouses)
Dim i As Integer
For i = 1 To nWarehouses
warehouseList(i) = .Offset(i, 0)
Next
End If
End With

'    Worksheets("Sheet1").Activate
'    With Range("Anchor")
'    Dim w As Integer
'    For w = 1 To nWarehouses
'        .Offset(w, 1).Value = warehouseList(w)
'    Next
'    End With


End Sub
Sub GetDCs()
' This sub finds the number of DCs and their corresponding data.
Worksheets("DCS").Select
With Range("DCAnchor")
If .Offset(1, 0).Value = "" Then
MsgBox "First DC has not been entered !!!", vbExclamation, "Infeasible"
End
Else
nDCs = Range(.Offset(1, 0), .End(xlDown)).Count
ReDim DCList(nDCs)
ReDim isSelectedDC(nDCs)
Dim i As Integer
For i = 1 To nDCs
DCList(i) = .Offset(i, 0)
Next
End If
End With

'    Worksheets("Sheet1").Activate
'    With Range("Anchor")
'    Dim w As Integer
'    For w = 1 To nDCs
'        .Offset(w, 1).Value = DCList(w)
'    Next
'    End With


End Sub
```

```vba
Sub GetZones()
' This sub finds the number of Customer Zones and their corresponding data.
Worksheets("CUSTOMER ZONES").Select
With Range("ZoneAnchor")
If .Offset(1, 0).Value = "" Then
MsgBox "First Zone has not been entered !!!", vbExclamation, "Infeasible"
End
Else
nZones = Range(.Offset(1, 0), .End(xlDown)).Count
ReDim ZoneList(nZones)
ReDim isSelectedZone(nZones)
Dim i As Integer
For i = 1 To nZones
ZoneList(i) = .Offset(i, 0)
Next
End If
End With

'    Worksheets("Sheet1").Activate
'    With Range("Anchor")
'    Dim w As Integer
'    For w = 1 To nZones
'        .Offset(w, 1).Value = ZoneList(w)
'    Next
'    End With

End Sub
Sub GetPlantResources()
' This sub finds the number of plant resources and their corresponding data.
Worksheets("PLANTS").Select
With Range("PlantAnchor")
nPlants = Range(.Offset(1, 0), .End(xlDown)).Count
nResourcePlants = Range(.Offset(1, 2), .Offset(1, 2).End(xlToRight)).Count
Dim i As Integer, j As Integer
For i = 1 To nPlants
For j = 1 To nResourcePlants
resourceplantList(i, j) = .Offset(i, j + 1).Value
Next
Next
End With
'    Worksheets("Sheet1").Activate
'    With Range("Anchor")
'    Dim w As Integer, z As Integer
'      For w = 1 To nPlants
'        For z = 1 To nResourcePlants
'        .Offset(w, z).Value = resourceplantList(w, z)
'        Next
'      Next
'    End With

End Sub
Sub GetwarehouseResources()
' This sub finds the number of warehouse resources and their corresponding data.
Worksheets("WAREHOUSES").Select
With Range("WarehouseAnchor")
nWarehouses = Range(.Offset(1, 0), .End(xlDown)).Count
nResourcewarehouses = Range(.Offset(1, 2), .Offset(1, 2).End(xlToRight)).Count
Dim i As Integer, j As Integer
For i = 1 To nWarehouses
For j = 1 To nResourcewarehouses
resourcewarehouseList(i, j) = .Offset(i, j + 1).Value
Next
Next
End With

'    Worksheets("Sheet1").Activate
'    With Range("Anchor")
'    Dim w As Integer, z As Integer
```

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'       For w = 1 To nWarehouses
'         For z = 1 To nResourceWarehouses
'         .Offset(w, z).Value = resourcewarehouseList(w, z)
'         Next
'       Next
'    End With

End Sub
Sub GetDCResources()
' This sub finds the number of DC resources and their corresponding data.
Worksheets("DCS").Select
With Range("DCAnchor")
nDCs = Range(.Offset(1, 0), .End(xlDown)).Count
nResourceDCs = Range(.Offset(1, 2), .Offset(1, 2).End(xlToRight)).Count
Dim i As Integer, j As Integer
For i = 1 To nDCs
For j = 1 To nResourceDCs
resourceDCList(i, j) = .Offset(i, j + 1).Value
Next
Next
End With

'    Worksheets("Sheet1").Activate
'    With Range("Anchor")
'    Dim w As Integer, z As Integer
'       For w = 1 To nDCs
'         For z = 1 To nResourceDCs
'         .Offset(w, z).Value = resourceDCList(w, z)
'         Next
'       Next
'    End With

End Sub
Sub GetZoneResources()
' This sub finds the number of customer zone resources and their corresponding data.
Worksheets("CUSTOMER ZONES").Select
With Range("ZoneAnchor")
nZones = Range(.Offset(1, 0), .End(xlDown)).Count
nResourceZones = Range(.Offset(1, 1), .Offset(1, 0).End(xlToRight)).Count
'       Range("B15").Value = nResourceZones
'       nResourceZones = 1
     Dim i As Integer, j As Integer
     For i = 1 To nZones
       For j = 1 To nResourceZones
       resourcezoneList(i, j) = .Offset(i, j).Value
       Next
     Next
   End With

'    Worksheets("Sheet1").Activate
'    With Range("Anchor")
'    Dim w As Integer, z As Integer
'       For w = 1 To nZones
'         For z = 1 To nResourceZones
'         .Offset(w, z).Value = resourcezoneList(w, z)
'         Next
'       Next
'    End With

End Sub
Sub SetupModel()
' This sub develops the optimization model through a series of subroutines.
With Worksheets("Model")
.Visible = True
.Activate
End With
Call ClearOldModel
Call EnterSupplyChainData
```

```
Call CalcMonetaryValues
Call RunSolver
End Sub
Sub ClearOldModel()
' This sub clears all of the old data, but not formatting, from any previous model.
With Range("ModelAnchor")
Range(.Offset(0, 0), .Offset(10000, 100)).Select
Range(.Offset(0, 0), .Offset(10000, 100)).ClearContents
Selection.Interior.ColorIndex = xlNone
Range("A1").Select
End With

End Sub
Sub EnterSupplyChainData()
' This sub enters the plant and resource data for all plants selected in the
' suply chain mix part of the Model sheet.
Dim plantIndex As Integer, warehouseIndex As Integer
Dim DCIndex As Integer, ZoneIndex As Integer
Dim plantI As Integer, warehouseI As Integer
Dim DCI As Integer, ZoneI As Integer
Dim i As Integer, j As Integer, k As Integer, m As Integer, z As Integer
Dim conversion As Variant, freedomindex As Variant

freedomindex = Range("freedomindex")
conversion = Range("conversiontons")

' Enter data only for the selected plants, where plantIndex is a counter for these.
k = 0
m = 0
plantIndex = 0

Worksheets("Model").Activate
With Range("ModelAnchor")
    '
' Enter all data from worksheet PLANTS.
    '
For i = 1 To nPlants
If isSelectedPlant(i) Then
k = k + 1
plantIndex = plantIndex + 1

' Enter plant name.
.Offset(k, plantIndex) = plantList(i)

' Enter all the plant resources
For j = 1 To nResourcePlants - 1
k = k + 1
If j = 1 Or j = 2 Then
.Offset(k, plantIndex).FormulaR1C1 = "=" & resourceplantList(i, j) & "/" & conversion
Else
.Offset(k, plantIndex).Value = resourceplantList(i, j)
End If
Next
' Calculate unit freedom index.
k = k + 1
If freedomindex = "YES" Then
.Offset(k, plantIndex).Value = (100 - resourceplantList(i, j))
Else
.Offset(k, plantIndex).Value = 0
End If

' Set the initial values of the binary changing cells to 1.
k = k + 1
.Offset(k, plantIndex) = 1

' Calculate new min and max by multiplying by plant binary.
k = k + 1
.Offset(k, plantIndex).FormulaR1C1 = "=R[-4]C*R[-1]C"
```

```
k = k + 1
.Offset(k, plantIndex).FormulaR1C1 = "=R[-4]C*R[-2]C"

' Set the initial values of the (dv) changing cells to 0.
k = k + 1
.Offset(k, plantIndex) = 0

End If
k = 0
Next
'Enter heading
.Offset(m, 1) = "Plants"
Range(.Offset(m, 1), .Offset(m, 1)).Select
With Selection.Interior
.ColorIndex = 6
.Pattern = xlSolid
End With
Selection.Merge

' Name various ranges and display names on the worksheet
Range(.Offset(m + 2, 1), .Offset(m + 2, 1).End(xlToRight)).Name = "CostUnit"
Range(.Offset(m + 2, 1), .Offset(m + 2, 1).End(xlToRight)).Select
Selection.NumberFormat = "$#,##0.00"
.Offset(m + 2, 0) = "Unit Cost"

Range(.Offset(m + 3, 1), .Offset(m + 3, 1).End(xlToRight)).Name = "PlantTransferPrice"
Range(.Offset(m + 3, 1), .Offset(m + 3, 1).End(xlToRight)).Select
Selection.NumberFormat = "$#,##0.00"
.Offset(m + 3, 0) = "Transfer Price per Unit"

Range(.Offset(m + 4, 1), .Offset(m + 4, 1).End(xlToRight)).Name = "PlantFixedCost"
Range(.Offset(m + 4, 1), .Offset(m + 4, 1).End(xlToRight)).Select
Selection.NumberFormat = "$#,##0"
.Offset(m + 4, 0) = "Fixed Cost"

Range(.Offset(m + 5, 1), .Offset(m + 5, 1).End(xlToRight)).Select
Selection.NumberFormat = "0.00"
.Offset(m + 5, 0) = "Plant Minimum"

Range(.Offset(m + 6, 1), .Offset(m + 6, 1).End(xlToRight)).Select
Selection.NumberFormat = "0.00"
.Offset(m + 6, 0) = "Plant Maximum"

Range(.Offset(m + 7, 1), .Offset(m + 7, 1).End(xlToRight)).Name = "PlantFreedom"
Range(.Offset(m + 7, 1), .Offset(m + 7, 1).End(xlToRight)).Select
Selection.NumberFormat = "0.00"
.Offset(m + 7, 0) = "Freedom Index"

Range(.Offset(m + 8, 1), .Offset(m + 8, 1).End(xlToRight)).Name = "PlantBinary"
Range(.Offset(m + 8, 1), .Offset(m + 8, 1).End(xlToRight)).Select
Selection.NumberFormat = "0.00"
.Offset(m + 8, 0) = "Y_Binary"

Range(.Offset(m + 9, 1), .Offset(m + 9, 1).End(xlToRight)).Name = "PlantMin"
Range(.Offset(m + 9, 1), .Offset(m + 9, 1).End(xlToRight)).Select
Selection.NumberFormat = "0.00"
.Offset(m + 9, 0) = "Y_Minimum"

Range(.Offset(m + 10, 1), .Offset(m + 10, 1).End(xlToRight)).Name = "PlantMax"
Range(.Offset(m + 10, 1), .Offset(m + 10, 1).End(xlToRight)).Select
Selection.NumberFormat = "0.00"
.Offset(m + 10, 0) = "Y_Maximum"

Range(.Offset(m + 11, 1), .Offset(m + 11, 1).End(xlToRight)).Name = "PlantDV"
Range(.Offset(m + 11, 1), .Offset(m + 11, 1).End(xlToRight)).Select
Selection.NumberFormat = "0.00"
With Selection.Interior
.ColorIndex = 4
```

```
.Pattern = xlSolid
End With
.Offset(m + 11, 0) = "Decision Variable"

' Obtain the last row and skip a row to start next table
m = Range(.Offset(m, 1), .Offset(m, 1).End(xlDown)).Count
m = m + 1
k = m
warehouseIndex = 0
        '
' Enter all data from worksheet WAREHOUSES
        '
For i = 1 To nWarehouses
If isSelectedWarehouse(i) Then
k = k + 1
warehouseIndex = warehouseIndex + 1

' Enter warehouse name.
.Offset(k, warehouseIndex) = warehouseList(i)

' Enter all the warehouse resources
For j = 1 To nResourcewarehouses - 1
k = k + 1
If j = 1 Or j = 2 Then
.Offset(k, warehouseIndex).FormulaR1C1 = "=" & resourcewarehouseList(i, j) & "/" & conversion
Else
.Offset(k, warehouseIndex).Value = resourcewarehouseList(i, j)
End If
Next
' Calculate unit freedom index.
k = k + 1
If freedomindex = "YES" Then
.Offset(k, warehouseIndex).Value = (100 - resourcewarehouseList(i, j))
Else
.Offset(k, warehouseIndex).Value = 0
End If

' Set the initial values of the binary changing cells to 1.
k = k + 1
.Offset(k, warehouseIndex) = 1

' Calculate new min and max by multiplying by warehouse binary.
k = k + 1
.Offset(k, warehouseIndex).FormulaR1C1 = "=R[-4]C*R[-1]C"
k = k + 1
.Offset(k, warehouseIndex).FormulaR1C1 = "=R[-4]C*R[-2]C"

' Skip one line for entering the changing cells
k = k + 1
' Set the initial values of the (dv) changing cells to 0.
For z = 1 To plantIndex
k = k + 1
.Offset(k, warehouseIndex) = 0
Next

End If
k = m
Next
'Enter heading
.Offset(m, 1) = "Warehouse"
Range(.Offset(m, 1), .Offset(m, 1)).Select
With Selection.Interior
.ColorIndex = 6
.Pattern = xlSolid
End With
Selection.Merge

' Name various ranges and display names on the worksheet
```

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Range(.Offset(m + 2, 1), .Offset(m + 2, 1).End(xlToRight)).Name = "WarehouseHandlingCost"
Range(.Offset(m + 2, 1), .Offset(m + 2, 1).End(xlToRight)).Select
Selection.NumberFormat = "$#,##0.00"
.Offset(m + 2, 0) = "Handling Cost"

Range(.Offset(m + 3, 1), .Offset(m + 3, 1).End(xlToRight)).Name = "WarehouseTransferPrice"
Range(.Offset(m + 3, 1), .Offset(m + 3, 1).End(xlToRight)).Select
Selection.NumberFormat = "$#,##0.00"
.Offset(m + 3, 0) = "Transfer Price per Unit"

Range(.Offset(m + 4, 1), .Offset(m + 4, 1).End(xlToRight)).Name = "WarehouseFixedCost"
Range(.Offset(m + 4, 1), .Offset(m + 4, 1).End(xlToRight)).Select
Selection.NumberFormat = "$#,##0"
.Offset(m + 4, 0) = "Fixed Cost"

Range(.Offset(m + 5, 1), .Offset(m + 5, 1).End(xlToRight)).Name = "WarehouseDutiesTariffs"
Range(.Offset(m + 5, 1), .Offset(m + 5, 1).End(xlToRight)).Select
Selection.NumberFormat = "0.00%"
.Offset(m + 5, 0) = "Duties & Tariffs"

Range(.Offset(m + 6, 1), .Offset(m + 6, 1).End(xlToRight)).Select
Selection.NumberFormat = "0.00"
.Offset(m + 6, 0) = "Warehouse Minimum"

Range(.Offset(m + 7, 1), .Offset(m + 7, 1).End(xlToRight)).Select
Selection.NumberFormat = "0.00"
.Offset(m + 7, 0) = "Warehouse Maximum"

Range(.Offset(m + 8, 1), .Offset(m + 8, 1).End(xlToRight)).Name = "WarehouseFreedom"
Range(.Offset(m + 8, 1), .Offset(m + 8, 1).End(xlToRight)).Select
Selection.NumberFormat = "0.00"
.Offset(m + 8, 0) = "Freedom Index"

Range(.Offset(m + 9, 1), .Offset(m + 9, 1).End(xlToRight)).Name = "WarehouseBinary"
Range(.Offset(m + 9, 1), .Offset(m + 9, 1).End(xlToRight)).Select
Selection.NumberFormat = "0.00"
.Offset(m + 9, 0) = "Y_Binary"

Range(.Offset(m + 10, 1), .Offset(m + 10, 1).End(xlToRight)).Name = "WarehouseMin"
Range(.Offset(m + 10, 1), .Offset(m + 10, 1).End(xlToRight)).Select
Selection.NumberFormat = "0.00"
.Offset(m + 10, 0) = "Y_Minimum"

Range(.Offset(m + 11, 1), .Offset(m + 11, 1).End(xlToRight)).Name = "WarehouseMax"
Range(.Offset(m + 11, 1), .Offset(m + 11, 1).End(xlToRight)).Select
Selection.NumberFormat = "0.00"
.Offset(m + 11, 0) = "Y_Maximum"

.Offset(m + 12, 0) = "Plant"
z = 0
For i = 1 To nWarehouses
If isSelectedWarehouse(i) Then
z = z + 1
.Offset(m + 12, z) = warehouseList(i)
End If
Next
z = 0
For i = 1 To nPlants
If isSelectedPlant(i) Then
z = z + 1
.Offset(m + 12 + z, 0) = plantList(i)
End If
Next
Range(.Offset(m + 12, 0), .Offset(m + 12, 0).End(xlDown).End(xlToRight)).Name = "PlantWarehouseDV_G"
Range(.Offset(m + 13, 1), .Offset(m + 13, 1).End(xlDown).End(xlToRight)).Name = "PlantWarehouseDV"
Range(.Offset(m + 13, 1), .Offset(m + 13, 1).End(xlDown).End(xlToRight)).Select
Selection.NumberFormat = "0"
With Selection.Interior
```

```
.ColorIndex = 4
.Pattern = xlSolid
End With

' this sub creates TOTAL formulas at the end of the DV tables
.Offset(m + 12, warehouseIndex + 1) = "Total"
Range(.Offset(m + 13, warehouseIndex + 1), .Offset(m + 12 + plantIndex, warehouseIndex + 1)).FormulaR1C1 = _
"=SUM(RC[-" & warehouseIndex & "]:RC[-1])"
Range(.Offset(m + 13, warehouseIndex + 1), .Offset(m + 12 + plantIndex, warehouseIndex + 1)).Name = "Sum_Plants"
Range(.Offset(m + 13, warehouseIndex + 1), .Offset(m + 12 + plantIndex, warehouseIndex + 1)).Select
Selection.NumberFormat = "0"
With Selection.Interior
.ColorIndex = 8
.Pattern = xlSolid
End With
.Offset(m + 13 + plantIndex, 0) = "Total"
Range(.Offset(m + 13 + plantIndex, 1), .Offset(m + 13 + plantIndex, warehouseIndex)).FormulaR1C1 = _
"=SUM(R[-" & plantIndex & "]C:R[-1]C)"
Range(.Offset(m + 13 + plantIndex, 1), .Offset(m + 13 + plantIndex, warehouseIndex)).Name = "Sum1_Warehouses"
Range(.Offset(m + 13 + plantIndex, 1), .Offset(m + 13 + plantIndex, warehouseIndex)).Select
Selection.NumberFormat = "0"
With Selection.Interior
.ColorIndex = 8
.Pattern = xlSolid
End With
' Obtain the last row and skip a row to start next table
m = Range(.Offset(m, 1), .Offset(m, 1).End(xlDown)).Count
k = k + m + 1
m = k
DCIndex = 0
    '
' Enter all data from worksheet DCS
    '
For i = 1 To nDCs
If isSelectedDC(i) Then
k = k + 1
DCIndex = DCIndex + 1

' Enter DC name.
.Offset(k, DCIndex) = DCList(i)

' Enter all the DC resources
For j = 1 To nResourceDCs - 1
k = k + 1
If j = 1 Or j = 2 Then
.Offset(k, DCIndex).FormulaR1C1 = "=" & resourceDCList(i, j) & "/" & conversion
Else
.Offset(k, DCIndex).Value = resourceDCList(i, j)
End If
Next
' Calculate unit freedom index.
k = k + 1
If freedomindex = "YES" Then
.Offset(k, DCIndex).Value = (100 - resourceDCList(i, j))
Else
.Offset(k, DCIndex).Value = 0
End If

' Set the initial values of the binary changing cells to 1.
k = k + 1
.Offset(k, DCIndex) = 1

' Calculate new min and max by multiplying by warehouse binary.
k = k + 1
.Offset(k, DCIndex).FormulaR1C1 = "=R[-4]C*R[-1]C"
k = k + 1
.Offset(k, DCIndex).FormulaR1C1 = "=R[-4]C*R[-2]C"
```

```
' Skip another one line for entering the changing cells
k = k + 1
' Set the initial values of the (dv) changing cells to 0.
For z = 1 To warehouseIndex
k = k + 1
.Offset(k, DCIndex) = 0
Next

End If
k = m
Next
'Enter heading
.Offset(m, 1) = "Distribution Center"
Range(.Offset(m, 1), .Offset(m, 1)).Select
With Selection.Interior
.ColorIndex = 6
.Pattern = xlSolid
End With
Selection.Merge

' Name various ranges and display names on the worksheet
Range(.Offset(m + 2, 1), .Offset(m + 2, 1).End(xlToRight)).Name = "DCHandlingCost"
Range(.Offset(m + 2, 1), .Offset(m + 2, 1).End(xlToRight)).Select
Selection.NumberFormat = "$#,##0.00"
.Offset(m + 2, 0) = "Handling Cost"

Range(.Offset(m + 3, 1), .Offset(m + 3, 1).End(xlToRight)).Name = "DCTransferPrice"
Range(.Offset(m + 3, 1), .Offset(m + 3, 1).End(xlToRight)).Select
Selection.NumberFormat = "$#,##0.00"
.Offset(m + 3, 0) = "Transfer Price per Unit"

Range(.Offset(m + 4, 1), .Offset(m + 4, 1).End(xlToRight)).Name = "DCFixedCost"
Range(.Offset(m + 4, 1), .Offset(m + 4, 1).End(xlToRight)).Select
Selection.NumberFormat = "$#,##0"
.Offset(m + 4, 0) = "Fixed Cost"

Range(.Offset(m + 5, 1), .Offset(m + 5, 1).End(xlToRight)).Name = "DCDutiesTariffs"
Range(.Offset(m + 5, 1), .Offset(m + 5, 1).End(xlToRight)).Select
Selection.NumberFormat = "0.00%"
.Offset(m + 5, 0) = "Duties & Tariffs"

Range(.Offset(m + 6, 1), .Offset(m + 6, 1).End(xlToRight)).Select
Selection.NumberFormat = "0.00"
.Offset(m + 6, 0) = "DC Minimum"

Range(.Offset(m + 7, 1), .Offset(m + 7, 1).End(xlToRight)).Select
Selection.NumberFormat = "0.00"
.Offset(m + 7, 0) = "DC Maximum"

Range(.Offset(m + 8, 1), .Offset(m + 8, 1).End(xlToRight)).Name = "DCFreedom"
Range(.Offset(m + 8, 1), .Offset(m + 8, 1).End(xlToRight)).Select
Selection.NumberFormat = "0.00"
.Offset(m + 8, 0) = "Freedom Index"

Range(.Offset(m + 9, 1), .Offset(m + 9, 1).End(xlToRight)).Name = "DCBinary"
Range(.Offset(m + 9, 1), .Offset(m + 9, 1).End(xlToRight)).Select
Selection.NumberFormat = "0.00"
.Offset(m + 9, 0) = "Y_Binary"

Range(.Offset(m + 10, 1), .Offset(m + 10, 1).End(xlToRight)).Name = "DCMin"
Range(.Offset(m + 10, 1), .Offset(m + 10, 1).End(xlToRight)).Select
Selection.NumberFormat = "0.00"
.Offset(m + 10, 0) = "Y_Minimum"

Range(.Offset(m + 11, 1), .Offset(m + 11, 1).End(xlToRight)).Name = "DCMax"
Range(.Offset(m + 11, 1), .Offset(m + 11, 1).End(xlToRight)).Select
Selection.NumberFormat = "0.00"
.Offset(m + 11, 0) = "Y_Maximum"
```

```
.Offset(m + 12, 0) = "Warehouse"
z = 0
For i = 1 To nDCs
If isSelectedDC(i) Then
z = z + 1
.Offset(m + 12, z) = DCList(i)
End If
Next
z = 0
For i = 1 To nWarehouses
If isSelectedWarehouse(i) Then
z = z + 1
.Offset(m + 12 + z, 0) = warehouseList(i)
End If
Next
Range(.Offset(m + 12, 0), .Offset(m + 12, 0).End(xlDown).End(xlToRight)).Name = "WarehouseDCDV_G"
Range(.Offset(m + 13, 1), .Offset(m + 13, 1).End(xlDown).End(xlToRight)).Name = "WarehouseDCDV"
Range(.Offset(m + 13, 1), .Offset(m + 13, 1).End(xlDown).End(xlToRight)).Select
Selection.NumberFormat = "0"
With Selection.Interior
.ColorIndex = 4
.Pattern = xlSolid
End With

' this sub creates TOTAL formulas at the end of the DV tables
.Offset(m + 12, DCIndex + 1) = "Total"
Range(.Offset(m + 13, DCIndex + 1), .Offset(m + 12 + warehouseIndex, DCIndex + 1)).FormulaR1C1 = _
"=SUM(RC[-" & DCIndex & "]:RC[-1])"
Range(.Offset(m + 13, DCIndex + 1), .Offset(m + 12 + warehouseIndex, DCIndex + 1)).Name = "Sum2_Warehouses"
Range(.Offset(m + 13, DCIndex + 1), .Offset(m + 12 + warehouseIndex, DCIndex + 1)).Select
Selection.NumberFormat = "0"
With Selection.Interior
.ColorIndex = 8
.Pattern = xlSolid
End With
.Offset(m + 13 + warehouseIndex, 0) = "Total"
Range(.Offset(m + 13 + warehouseIndex, 1), .Offset(m + 13 + warehouseIndex, DCIndex)).FormulaR1C1 = _
"=SUM(R[-" & warehouseIndex & "]C:R[-1]C)"
Range(.Offset(m + 13 + warehouseIndex, 1), .Offset(m + 13 + warehouseIndex, DCIndex)).Name = "Sum1_DCs"
Range(.Offset(m + 13 + warehouseIndex, 1), .Offset(m + 13 + warehouseIndex, DCIndex)).Select
Selection.NumberFormat = "0"
With Selection.Interior
.ColorIndex = 8
.Pattern = xlSolid
End With
' Obtain the last row and skip a row to start next table
m = Range(.Offset(m, 1), .Offset(m, 1).End(xlDown)).Count
k = k + m + 1
m = k

ZoneIndex = 0
        '
' Enter all data from worksheet Zones
        '
For i = 1 To nZones
If isSelectedZone(i) Then
k = k + 1
ZoneIndex = ZoneIndex + 1

' Enter DC name.
.Offset(k, ZoneIndex) = ZoneList(i)

' Enter the customer zone demand.
k = k + 1
.Offset(k, ZoneIndex).Value = resourcezoneList(i, 1)

' Skip another line for entering the changing cells
```

```
k = k + 1
' Set the initial values of the (dv) changing cells to 0.

For z = 1 To DCIndex
k = k + 1
.Offset(k, ZoneIndex) = 0
Next

End If
k = m
Next
'Enter heading
.Offset(m, 1) = "Customer Zone"
Range(.Offset(m, 1), .Offset(m, 1)).Select
With Selection.Interior
.ColorIndex = 6
.Pattern = xlSolid
End With
Selection.Merge

' Name various ranges and display names on the worksheet
Range(.Offset(m + 2, 1), .Offset(m + 2, 1).End(xlToRight)).Name = "CustomerDemand"
Range(.Offset(m + 2, 1), .Offset(m + 2, 1).End(xlToRight)).Select
Selection.NumberFormat = "0.00"
.Offset(m + 2, 0) = "Demand"

.Offset(m + 3, 0) = "DCs"
z = 0
For i = 1 To nZones
If isSelectedZone(i) Then
z = z + 1
.Offset(m + 3, z) = ZoneList(i)
End If
Next
z = 0
For i = 1 To nDCs
If isSelectedDC(i) Then
z = z + 1
.Offset(m + 3 + z, 0) = DCList(i)
End If
Next
Range(.Offset(m + 3, 0), .Offset(m + 3, 0).End(xlDown).End(xlToRight)).Name = "DCZoneDV_G"
Range(.Offset(m + 4, 1), .Offset(m + 4, 1).End(xlDown).End(xlToRight)).Name = "DCZoneDV"
Range(.Offset(m + 4, 1), .Offset(m + 4, 1).End(xlDown).End(xlToRight)).Select
Selection.NumberFormat = "0"
With Selection.Interior
.ColorIndex = 4
.Pattern = xlSolid
End With

' this sub creates TOTAL formulas at the end of the DV tables
.Offset(m + 3, ZoneIndex + 1) = "Total"
Range(.Offset(m + 4, ZoneIndex + 1), .Offset(m + 3 + DCIndex, ZoneIndex + 1)).FormulaR1C1 = _
"=SUM(RC[-" & ZoneIndex & "]:RC[-1])"
Range(.Offset(m + 4, ZoneIndex + 1), .Offset(m + 3 + DCIndex, ZoneIndex + 1)).Name = "Sum2_DCs"
Range(.Offset(m + 4, ZoneIndex + 1), .Offset(m + 3 + DCIndex, ZoneIndex + 1)).Select
Selection.NumberFormat = "0"
With Selection.Interior
.ColorIndex = 8
.Pattern = xlSolid
End With
.Offset(m + 4 + DCIndex, 0) = "Total"
Range(.Offset(m + 4 + DCIndex, 1), .Offset(m + 4 + DCIndex, ZoneIndex)).FormulaR1C1 = _
"=SUM(R[-" & DCIndex & "]C:R[-1]C)"
Range(.Offset(m + 4 + DCIndex, 1), .Offset(m + 4 + DCIndex, ZoneIndex)).Name = "Sum1_Zones"
Range(.Offset(m + 4 + DCIndex, 1), .Offset(m + 4 + DCIndex, ZoneIndex)).Select
Selection.NumberFormat = "0"
With Selection.Interior
```

```
.ColorIndex = 8
.Pattern = xlSolid
End With
' Obtain the last row and skip a row to start next table
m = Range(.Offset(m, 1), .Offset(m, 1).End(xlDown)).Count
k = k + m + 1
m = k


' Display headings of X-Binary DVs table - Plant to Warehouse
.Offset(m, 1) = "X-Binary DV - PtoW"
Range(.Offset(m, 1), .Offset(m, 1)).Select
Selection.NumberFormat = "0"
With Selection.Interior
.ColorIndex = 13
.Pattern = xlSolid
End With
Selection.Merge

.Offset(m + 1, 0) = "Plant"
z = 0
For i = 1 To nWarehouses
If isSelectedWarehouse(i) Then
z = z + 1
.Offset(m + 1, z) = warehouseList(i)
End If
Next
z = 0
For i = 1 To nPlants
If isSelectedPlant(i) Then
z = z + 1
.Offset(m + 1 + z, 0) = plantList(i)
End If
Next
' Skip another line for entering the changing cells
k = k + 1
' Set the initial values of the (dv) changing cells to 0.
For i = 1 To plantIndex
k = k + 1
For z = 1 To warehouseIndex
.Offset(k, z) = 0
Next
Next
k = m
Range(.Offset(m + 2, 1), .Offset(m + 2, 1).End(xlDown).End(xlToRight)).Select
Selection.NumberFormat = "0"
With Selection.Interior
.ColorIndex = 12
.Pattern = xlSolid
End With

' Name the X-Binary Matrix - Plant to Warehouse
Range(.Offset(m + 2, 1), .Offset(m + 2, 1).End(xlDown).End(xlToRight)).Name = "PlantWarehouseDV_X"
' Obtain the last row and skip a row to start next table
m = Range(.Offset(m, 1), .Offset(m, 1).End(xlDown)).Count
k = k + m + 1
m = k


' Display headings of X-Binary DVs table - Warehouse to DC
.Offset(m, 1) = "X-Binary DV - WtoDC"
Range(.Offset(m, 1), .Offset(m, 1)).Select
Selection.NumberFormat = "0"
With Selection.Interior
.ColorIndex = 13
.Pattern = xlSolid
End With
Selection.Merge
```

```vba
.Offset(m + 1, 0) = "Warehouse"
z = 0
For i = 1 To nDCs
If isSelectedDC(i) Then
z = z + 1
.Offset(m + 1, z) = DCList(i)
End If
Next
z = 0
For i = 1 To nWarehouses
If isSelectedWarehouse(i) Then
z = z + 1
.Offset(m + 1 + z, 0) = warehouseList(i)
End If
Next
' Skip another line for entering the changing cells
k = k + 1
' Set the initial values of the (dv) changing cells to 0.
For i = 1 To warehouseIndex
k = k + 1
For z = 1 To DCIndex
.Offset(k, z) = 0
Next
Next
k = m
Range(.Offset(m + 2, 1), .Offset(m + 2, 1).End(xlDown).End(xlToRight)).Name = "WarehouseDCDV_X"
Range(.Offset(m + 2, 1), .Offset(m + 2, 1).End(xlDown).End(xlToRight)).Select
Selection.NumberFormat = "0"
With Selection.Interior
.ColorIndex = 12
.Pattern = xlSolid
End With

' Obtain the last row and skip a row to start next table
m = Range(.Offset(m, 1), .Offset(m, 1).End(xlDown)).Count
k = k + m + 1
m = k


' Display headings of X-Binary DVs table - DC to Zones
.Offset(m, 1) = "X-Binary DV - DCtoZ"
Range(.Offset(m, 1), .Offset(m, 1)).Select
Selection.NumberFormat = "0"
With Selection.Interior
.ColorIndex = 13
.Pattern = xlSolid
End With
Selection.Merge

.Offset(m + 1, 0) = "DC"
z = 0
For i = 1 To nZones
If isSelectedZone(i) Then
z = z + 1
.Offset(m + 1, z) = ZoneList(i)
End If
Next
z = 0
For i = 1 To nDCs
If isSelectedDC(i) Then
z = z + 1
.Offset(m + 1 + z, 0) = DCList(i)
End If
Next
' Skip another line for entering the changing cells
k = k + 1
' Set the initial values of the (dv) changing cells to 0.
```

```
For i = 1 To DCIndex
k = k + 1
For z = 1 To ZoneIndex
.Offset(k, z) = 0
Next
Next
k = m
Range(.Offset(m + 2, 1), .Offset(m + 2, 1).End(xlDown).End(xlToRight)).Name = "DCZoneDV_X"
Range(.Offset(m + 2, 1), .Offset(m + 2, 1).End(xlDown).End(xlToRight)).Select
Selection.NumberFormat = "0"
With Selection.Interior
.ColorIndex = 12
.Pattern = xlSolid
End With

' Obtain the last row and skip a row to start next table
m = Range(.Offset(m, 1), .Offset(m, 1).End(xlDown)).Count
k = k + m + 1
m = k


' Display headings of Y-Binary table - Plant to Warehouse with Y-Binary Plants
.Offset(m, 1) = "Y-Binary Table - PtoW"
Range(.Offset(m, 1), .Offset(m, 1)).Select
With Selection.Interior
.ColorIndex = 14
.Pattern = xlSolid
End With
Selection.Merge

.Offset(m + 1, 0) = "Plant"
z = 0
For i = 1 To nWarehouses
If isSelectedWarehouse(i) Then
z = z + 1
.Offset(m + 1, z) = warehouseList(i)
End If
Next
z = 0
For i = 1 To nPlants
If isSelectedPlant(i) Then
z = z + 1
.Offset(m + 1 + z, 0) = plantList(i)
End If
Next
k = m + 1
plantI = 0
        '
' Enter all data from worksheet Y-Binary - Plants
        '
For j = 1 To nPlants
If isSelectedPlant(j) Then
k = k + 1
warehouseI = 0

For i = 1 To nWarehouses
If isSelectedWarehouse(i) Then
warehouseI = warehouseI + 1
' Enter formula of plant binary
.Offset(k, warehouseI).FormulaR1C1 = "=R[-" & m + plantI - 6 & "]C[" & plantI + 1 - warehouseI & "]"

End If
Next
plantI = plantI + 1
End If
Next
k = m
```

```
Range(.Offset(m + 2, 1), .Offset(m + 2, 1).End(xlDown).End(xlToRight)).Name = "PlantWarehouse_Y"
Range(.Offset(m + 2, 1), .Offset(m + 2, 1).End(xlDown).End(xlToRight)).Select
Selection.NumberFormat = "0"
With Selection.Interior
.ColorIndex = 18
.Pattern = xlSolid
End With

' Obtain the last row and skip a row to start next table
m = Range(.Offset(m, 1), .Offset(m, 1).End(xlDown)).Count
k = k + m + 1
m = k


' Display headings of Y-Binary table - Plant to Warehouse with Y-Binary Warehouse
.Offset(m, 1) = "Y-Binary Table - PtoW"
Range(.Offset(m, 1), .Offset(m, 1)).Select
With Selection.Interior
.ColorIndex = 14
.Pattern = xlSolid
End With
Selection.Merge

.Offset(m + 1, 0) = "Plant"
z = 0
For i = 1 To nWarehouses
If isSelectedWarehouse(i) Then
z = z + 1
.Offset(m + 1, z) = warehouseList(i)
End If
Next
z = 0
For i = 1 To nPlants
If isSelectedPlant(i) Then
z = z + 1
.Offset(m + 1 + z, 0) = plantList(i)
End If
Next
k = m + 1
plantI = 0
        '
' Enter all data from worksheet Y-Binary - Warehouses
        '
For j = 1 To nPlants
If isSelectedPlant(j) Then
k = k + 1
warehouseI = 0

For i = 1 To nWarehouses
If isSelectedWarehouse(i) Then
warehouseI = warehouseI + 1
' Enter formula of plant binary
.Offset(k, warehouseI).FormulaR1C1 = "=R[-" & m + plantI - 20 & "]C"

End If
Next
plantI = plantI + 1
End If
Next
k = m
Range(.Offset(m + 2, 1), .Offset(m + 2, 1).End(xlDown).End(xlToRight)).Name = "PlantWarehouse_Y2"
Range(.Offset(m + 2, 1), .Offset(m + 2, 1).End(xlDown).End(xlToRight)).Select
Selection.NumberFormat = "0"
With Selection.Interior
.ColorIndex = 18
.Pattern = xlSolid
End With
```

```
' Obtain the last row and skip a row to start next table
m = Range(.Offset(m, 1), .Offset(m, 1).End(xlDown)).Count
k = k + m + 1
m = k




' Display headings of Y-Binary table - Warehouse to DC with Y-Binary Warehouse
.Offset(m, 1) = "Y-Binary Table - WtoDC"
Range(.Offset(m, 1), .Offset(m, 1)).Select
With Selection.Interior
.ColorIndex = 14
.Pattern = xlSolid
End With
Selection.Merge

.Offset(m + 1, 0) = "Warehouse"
z = 0
For i = 1 To nDCs
If isSelectedDC(i) Then
z = z + 1
.Offset(m + 1, z) = DCList(i)
End If
Next
z = 0
For i = 1 To nWarehouses
If isSelectedWarehouse(i) Then
z = z + 1
.Offset(m + 1 + z, 0) = warehouseList(i)
End If
Next
k = m + 1
warehouseI = 0
            '
' Enter all data from Y-Binary - Warehouses
            '
For j = 1 To nWarehouses
If isSelectedWarehouse(j) Then
k = k + 1
DCI = 0

For i = 1 To nDCs
If isSelectedDC(i) Then
DCI = DCI + 1
' Enter formula of warehouse binary
.Offset(k, DCI).FormulaR1C1 = "=R[-" & m + warehouseI - 20 & "]C[" & warehouseI + 1 - DCI & "]"
End If
Next
warehouseI = warehouseI + 1
End If
Next
k = m
Range(.Offset(m + 2, 1), .Offset(m + 2, 1).End(xlDown).End(xlToRight)).Name = "WarehouseDC_Y"
Range(.Offset(m + 2, 1), .Offset(m + 2, 1).End(xlDown).End(xlToRight)).Select
Selection.NumberFormat = "0"
With Selection.Interior
.ColorIndex = 18
.Pattern = xlSolid
End With

' Obtain the last row and skip a row to start next table
m = Range(.Offset(m, 1), .Offset(m, 1).End(xlDown)).Count
k = k + m + 1
m = k




' Display headings of Y-Binary table - Warehouse to DC with Y-Binary DC
```

```vba
.Offset(m, 1) = "Y-Binary Table - WtoDC"
Range(.Offset(m, 1), .Offset(m, 1)).Select
With Selection.Interior
.ColorIndex = 14
.Pattern = xlSolid
End With
Selection.Merge

.Offset(m + 1, 0) = "Warehouse"
z = 0
For i = 1 To nDCs
If isSelectedDC(i) Then
z = z + 1
.Offset(m + 1, z) = DCList(i)
End If
Next
z = 0
For i = 1 To nWarehouses
If isSelectedWarehouse(i) Then
z = z + 1
.Offset(m + 1 + z, 0) = warehouseList(i)
End If
Next
k = m + 1
warehouseI = 0
        '
' Enter all data from Y-Binary - DCs
        '
For j = 1 To nWarehouses
If isSelectedWarehouse(j) Then
k = k + 1
DCI = 0

For i = 1 To nDCs
If isSelectedDC(i) Then
DCI = DCI + 1
' Enter formula of warehouse binary
.Offset(k, DCI).FormulaR1C1 = "=R[-" & m + warehouseI - plantIndex - 35 & "]C"
End If
Next
warehouseI = warehouseI + 1
End If
Next
k = m
Range(.Offset(m + 2, 1), .Offset(m + 2, 1).End(xlDown).End(xlToRight)).Name = "WarehouseDC_Y2"
Range(.Offset(m + 2, 1), .Offset(m + 2, 1).End(xlDown).End(xlToRight)).Select
Selection.NumberFormat = "0"
With Selection.Interior
.ColorIndex = 18
.Pattern = xlSolid
End With

' Obtain the last row and skip a row to start next table
m = Range(.Offset(m, 1), .Offset(m, 1).End(xlDown)).Count
k = k + m + 1
m = k

' Display headings of Y-Binary table - DC to Zones
.Offset(m, 1) = "Y-Binary Table - DCtoZ"
Range(.Offset(m, 1), .Offset(m, 1)).Select
With Selection.Interior
.ColorIndex = 14
.Pattern = xlSolid
End With
Selection.Merge

.Offset(m + 1, 0) = "DC"
```

```
z = 0
For i = 1 To nZones
If isSelectedZone(i) Then
z = z + 1
.Offset(m + 1, z) = ZoneList(i)
End If
Next
z = 0
For i = 1 To nDCs
If isSelectedDC(i) Then
z = z + 1
.Offset(m + 1 + z, 0) = DCList(i)
End If
Next
k = m + 1
DCI = 0
        '
' Enter all data from Y-Binary - DCs
        '
For j = 1 To nDCs
If isSelectedDC(j) Then
k = k + 1
ZoneI = 0

For i = 1 To nZones
If isSelectedZone(i) Then
ZoneI = ZoneI + 1
' Enter formula of DC binary
.Offset(k, ZoneI).FormulaR1C1 = "=R[-" & m + DCI - plantIndex - 35 & "]C[" & DCI + 1 - ZoneI & "]"

End If
Next
DCI = DCI + 1
End If
Next
k = m
Range(.Offset(m + 2, 1), .Offset(m + 2, 1).End(xlDown).End(xlToRight)).Name = "DCZone_Y"
Range(.Offset(m + 2, 1), .Offset(m + 2, 1).End(xlDown).End(xlToRight)).Select
Selection.NumberFormat = "0"
With Selection.Interior
.ColorIndex = 18
.Pattern = xlSolid
End With

' Obtain the last row and skip a row to start next table
m = Range(.Offset(m, 1), .Offset(m, 1).End(xlDown)).Count
k = k + m + 1
m = k


' Display headings of Maximum Capacity table - Plant to Warehouse
.Offset(m, 1) = "Maximum Capacity - X"
Range(.Offset(m, 1), .Offset(m, 1)).Select
With Selection.Interior
.ColorIndex = 21
.Pattern = xlSolid
End With
Selection.Merge

.Offset(m + 1, 0) = "Plant"
z = 0
For i = 1 To nWarehouses
If isSelectedWarehouse(i) Then
z = z + 1
.Offset(m + 1, z) = warehouseList(i)
End If
Next
z = 0
```

```
For i = 1 To nPlants
If isSelectedPlant(i) Then
z = z + 1
.Offset(m + 1 + z, 0) = plantList(i)
End If
Next
k = m + 1
        '
' Enter all data from worksheet CAPACITY TO WAREHOUSES
        '
For j = 1 To nPlants
If isSelectedPlant(j) Then
k = k + 1
warehouseI = 0
For i = 1 To nWarehouses
If isSelectedWarehouse(i) Then
warehouseI = warehouseI + 1
' Enter formula of maximum capacity * plant binary
.Offset(k, warehouseI).FormulaR1C1 = "=" & Worksheets("CAPACITY TO
WAREHOUSES").Range("capacityanchor_1").Offset(j, i).Value _
& "*R[-" & m - plantIndex - warehouseIndex - DCIndex - 49 & "]C"
End If
Next
End If
Next
k = m
Range(.Offset(m + 2, 1), .Offset(m + 2, 1).End(xlDown).End(xlToRight)).Name = "PlantWarehouse_MaxCapacityX"
Range(.Offset(m + 2, 1), .Offset(m + 2, 1).End(xlDown).End(xlToRight)).Select
Selection.NumberFormat = "0"
With Selection.Interior
.ColorIndex = 10
.Pattern = xlSolid
End With

' Obtain the last row and skip a row to start next table
m = Range(.Offset(m, 1), .Offset(m, 1).End(xlDown)).Count
k = k + m + 1
m = k


' Display headings of Maximum Capacity table - Warehouse to DC
.Offset(m, 1) = "Maximum Capacity - X"
Range(.Offset(m, 1), .Offset(m, 1)).Select
With Selection.Interior
.ColorIndex = 21
.Pattern = xlSolid
End With
Selection.Merge

.Offset(m + 1, 0) = "Warehouse"
z = 0
For i = 1 To nDCs
If isSelectedDC(i) Then
z = z + 1
.Offset(m + 1, z) = DCList(i)
End If
Next
z = 0
For i = 1 To nWarehouses
If isSelectedWarehouse(i) Then
z = z + 1
.Offset(m + 1 + z, 0) = warehouseList(i)
End If
Next
k = m + 1
        '
' Enter all data from worksheet CAPACITY TO DCs
        '
```

```
For j = 1 To nWarehouses
If isSelectedWarehouse(j) Then
k = k + 1
DCI = 0

For i = 1 To nDCs
If isSelectedDC(i) Then
DCI = DCI + 1
' Enter formula of maximum capacity * plant binary
.Offset(k, DCI).FormulaR1C1 = "=" & Worksheets("CAPACITY TO DCs").Range("capacityanchor_2").Offset(j, i).Value _
& "*R[-" & m - plantIndex - plantIndex - warehouseIndex - DCIndex - 52 & "]C"
End If
Next
End If
Next
k = m
Range(.Offset(m + 2, 1), .Offset(m + 2, 1).End(xlDown).End(xlToRight)).Select
Selection.NumberFormat = "0"
With Selection.Interior
.ColorIndex = 10
.Pattern = xlSolid
End With

' Name the Max Capacity Matrix - Warehouse to DC
Range(.Offset(m + 2, 1), .Offset(m + 2, 1).End(xlDown).End(xlToRight)).Name = "WarehouseDC_MaxCapacityX"
' Obtain the last row and skip a row to start next table
m = Range(.Offset(m, 1), .Offset(m, 1).End(xlDown)).Count
k = k + m + 1
m = k


' Display headings of Maximum Capacity table - DC to Zones
.Offset(m, 1) = "Maximum Capacity - X"
Range(.Offset(m, 1), .Offset(m, 1)).Select
With Selection.Interior
.ColorIndex = 21
.Pattern = xlSolid
End With
Selection.Merge

.Offset(m + 1, 0) = "DC"
z = 0
For i = 1 To nZones
If isSelectedZone(i) Then
z = z + 1
.Offset(m + 1, z) = ZoneList(i)
End If
Next
z = 0
For i = 1 To nDCs
If isSelectedDC(i) Then
z = z + 1
.Offset(m + 1 + z, 0) = DCList(i)
End If
Next
k = m + 1
        '
' Enter all data from worksheet CAPACITY TO ZONES
        '
For j = 1 To nDCs
If isSelectedDC(j) Then
k = k + 1
ZoneI = 0

For i = 1 To nZones
If isSelectedZone(i) Then
ZoneI = ZoneI + 1
' Enter formula of maximum capacity * plant binary
```

```
.Offset(k, ZoneI).FormulaR1C1 = “=” & Worksheets(“CAPACITY TO ZONES”).Range(“capacityanchor_3”).Offset(j, i).Value _
& “*R[-“ & m - plantIndex - plantIndex - warehouseIndex - warehouseIndex - DCIndex - 55 & “]C”
End If
Next
End If
Next
k = m
Range(.Offset(m + 2, 1), .Offset(m + 2, 1).End(xlDown).End(xlToRight)).Select
Selection.NumberFormat = “0”
With Selection.Interior
.ColorIndex = 10
.Pattern = xlSolid
End With

‘ Name the Max Capacity Matrix - DC to Zone
Range(.Offset(m + 2, 1), .Offset(m + 2, 1).End(xlDown).End(xlToRight)).Name = “DCZone_MaxCapacityX”
‘ Obtain the last row and skip a row to start next table
m = Range(.Offset(m, 1), .Offset(m, 1).End(xlDown)).Count
k = k + m + 1
m = k


‘ Display headings of LEAD TIME - Plant to Warehouse
.Offset(m, 1) = “Lead Time”
Range(.Offset(m, 1), .Offset(m, 1)).Select
With Selection.Interior
.ColorIndex = 22
.Pattern = xlSolid
End With
Selection.Merge

.Offset(m + 1, 0) = “Plant”
z = 0
For i = 1 To nWarehouses
If isSelectedWarehouse(i) Then
z = z + 1
.Offset(m + 1, z) = warehouseList(i)
End If
Next
z = 0
For i = 1 To nPlants
If isSelectedPlant(i) Then
z = z + 1
.Offset(m + 1 + z, 0) = plantList(i)
End If
Next
k = m + 1
        ‘
‘ Enter all data from worksheet LEADTIME TO WAREHOUSE
        ‘
For j = 1 To nPlants
If isSelectedPlant(j) Then
k = k + 1
warehouseI = 0
For i = 1 To nWarehouses
If isSelectedWarehouse(i) Then
warehouseI = warehouseI + 1
‘ Enter formula of lead time
.Offset(k, warehouseI).FormulaR1C1 = “=” & Worksheets(“LEADTIME TO
WAREHOUSES”).Range(“leadtimeanchor_1”).Offset(j, i).Value _
& “*” & 2400
End If
Next
End If
Next
k = m
Range(.Offset(m + 2, 1), .Offset(m + 2, 1).End(xlDown).End(xlToRight)).Name = “PlantWarehouse_LeadTime”
Range(.Offset(m + 2, 1), .Offset(m + 2, 1).End(xlDown).End(xlToRight)).Select
```

```
Selection.NumberFormat = "0"
With Selection.Interior
.ColorIndex = 12
.Pattern = xlSolid
End With

' Obtain the last row and skip a row to start next table
m = Range(.Offset(m, 1), .Offset(m, 1).End(xlDown)).Count
k = k + m + 1
m = k


' Display headings of LEAD TIME - Warehouse to DC
.Offset(m, 1) = "Lead Time"
Range(.Offset(m, 1), .Offset(m, 1)).Select
With Selection.Interior
.ColorIndex = 22
.Pattern = xlSolid
End With
Selection.Merge

.Offset(m + 1, 0) = "Warehouse"
z = 0
For i = 1 To nDCs
If isSelectedDC(i) Then
z = z + 1
.Offset(m + 1, z) = DCList(i)
End If
Next
z = 0
For i = 1 To nWarehouses
If isSelectedWarehouse(i) Then
z = z + 1
.Offset(m + 1 + z, 0) = warehouseList(i)
End If
Next
k = m + 1
        '
' Enter all data from worksheet LEADTIME TO DCS
        '
For j = 1 To nWarehouses
If isSelectedWarehouse(j) Then
k = k + 1
DCI = 0

For i = 1 To nDCs
If isSelectedDC(i) Then
DCI = DCI + 1
' Enter formula of lead time
.Offset(k, DCI).FormulaR1C1 = "=" & Worksheets("LEADTIME TO DCs").Range("leadtimeanchor_2").Offset(j, i).Value _
& "*" & 2400
End If
Next
End If
Next
k = m
Range(.Offset(m + 2, 1), .Offset(m + 2, 1).End(xlDown).End(xlToRight)).Name = "WarehouseDC_LeadTime"
Range(.Offset(m + 2, 1), .Offset(m + 2, 1).End(xlDown).End(xlToRight)).Select
Selection.NumberFormat = "0"
With Selection.Interior
.ColorIndex = 12
.Pattern = xlSolid
End With

' Obtain the last row and skip a row to start next table
m = Range(.Offset(m, 1), .Offset(m, 1).End(xlDown)).Count
k = k + m + 1
m = k
```

```vba
' Display headings of LEAD TIME - DC to Zones
.Offset(m, 1) = "Lead Time"
Range(.Offset(m, 1), .Offset(m, 1)).Select
With Selection.Interior
.ColorIndex = 22
.Pattern = xlSolid
End With
Selection.Merge

.Offset(m + 1, 0) = "DC"
z = 0
For i = 1 To nZones
If isSelectedZone(i) Then
z = z + 1
.Offset(m + 1, z) = ZoneList(i)
End If
Next
z = 0
For i = 1 To nDCs
If isSelectedDC(i) Then
z = z + 1
.Offset(m + 1 + z, 0) = DCList(i)
End If
Next
k = m + 1
        '
' Enter all data from worksheet LEADTIME TO ZONES
        '
For j = 1 To nDCs
If isSelectedDC(j) Then
k = k + 1
ZoneI = 0

For i = 1 To nZones
If isSelectedZone(i) Then
ZoneI = ZoneI + 1
' Enter formula of lead time
.Offset(k, ZoneI).FormulaR1C1 = "=" & Worksheets("LEADTIME TO ZONES").Range("leadtimeanchor_3").Offset(j, i).Value
_& "*" & 2400
End If
Next
End If
Next
k = m
Range(.Offset(m + 2, 1), .Offset(m + 2, 1).End(xlDown).End(xlToRight)).Name = "DCZone_LeadTime"
Range(.Offset(m + 2, 1), .Offset(m + 2, 1).End(xlDown).End(xlToRight)).Select
Selection.NumberFormat = "0"
With Selection.Interior
.ColorIndex = 12
.Pattern = xlSolid
End With

' Obtain the last row and skip a row to start next table
m = Range(.Offset(m, 1), .Offset(m, 1).End(xlDown)).Count
k = k + m + 1
m = k


' Display headings of Cost of Transportation - Plant to Warehouse
.Offset(m, 1) = "Transp. Cost - PtoW"
Range(.Offset(m, 1), .Offset(m, 1)).Select
With Selection.Interior
.ColorIndex = 5
.Pattern = xlSolid
End With
Selection.Merge
```

```
.Offset(m + 1, 0) = "Plant"
z = 0
For i = 1 To nWarehouses
If isSelectedWarehouse(i) Then
z = z + 1
.Offset(m + 1, z) = warehouseList(i)
End If
Next
z = 0
For i = 1 To nPlants
If isSelectedPlant(i) Then
z = z + 1
.Offset(m + 1 + z, 0) = plantList(i)
End If
Next
k = m + 1
        '
' Enter all data from worksheet COST TO WAREHOUSES * DISTANCE TO WAREHOUSES
        '
For j = 1 To nPlants
If isSelectedPlant(j) Then
k = k + 1
warehouseI = 0
For i = 1 To nWarehouses
If isSelectedWarehouse(i) Then
warehouseI = warehouseI + 1
' Enter formula of cost to warehouses * distance to warehouses
.Offset(k, warehouseI).FormulaR1C1 = "=" & Worksheets("COST TO WAREHOUSES").Range("costanchor_1").Offset(j,
i).Value _& "*" & Worksheets("DISTANCE TO WAREHOUSES").Range("distanceanchor_1").Offset(j, i).Value
End If
Next
End If
Next
k = m
Range(.Offset(m + 2, 1), .Offset(m + 2, 1).End(xlDown).End(xlToRight)).Name = "PlantWarehouse_Cost"
Range(.Offset(m + 2, 1), .Offset(m + 2, 1).End(xlDown).End(xlToRight)).Select
Selection.NumberFormat = "0"
With Selection.Interior
.ColorIndex = 4
.Pattern = xlSolid
End With

' Obtain the last row and skip a row to start next table
m = Range(.Offset(m, 1), .Offset(m, 1).End(xlDown)).Count
k = k + m + 1
m = k


' Display headings of Cost of Transportation - Warehouse to DC
.Offset(m, 1) = "Transp. Cost - WtoDC"
Range(.Offset(m, 1), .Offset(m, 1)).Select
With Selection.Interior
.ColorIndex = 5
.Pattern = xlSolid
End With
Selection.Merge

.Offset(m + 1, 0) = "Warehouse"
z = 0
For i = 1 To nDCs
If isSelectedDC(i) Then
z = z + 1
.Offset(m + 1, z) = DCList(i)
End If
Next
z = 0
For i = 1 To nWarehouses
```

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If isSelectedWarehouse(i) Then
z = z + 1
.Offset(m + 1 + z, 0) = warehouseList(i)
End If
Next
k = m + 1
        '
' Enter all data from worksheet COST TO DCs * DISTANCE TO DCs
        '
For j = 1 To nWarehouses
If isSelectedWarehouse(j) Then
k = k + 1
DCI = 0

For i = 1 To nDCs
If isSelectedDC(i) Then
DCI = DCI + 1
' Enter formula of cost to DCs * distance to DCs
.Offset(k, DCI).FormulaR1C1 = "=" & Worksheets("COST TO DCs").Range("costanchor_2").Offset(j, i).Value _
& "*" & Worksheets("DISTANCE TO DCs").Range("distanceanchor_2").Offset(j, i).Value
End If
Next
End If
Next
k = m
Range(.Offset(m + 2, 1), .Offset(m + 2, 1).End(xlDown).End(xlToRight)).Name = "WarehouseDC_Cost"
Range(.Offset(m + 2, 1), .Offset(m + 2, 1).End(xlDown).End(xlToRight)).Select
Selection.NumberFormat = "0"
With Selection.Interior
.ColorIndex = 4
.Pattern = xlSolid
End With

' Obtain the last row and skip a row to start next table
m = Range(.Offset(m, 1), .Offset(m, 1).End(xlDown)).Count
k = k + m + 1
m = k


' Display headings of Cost of Transportation - DC to Zones
.Offset(m, 1) = "Transp. Cost - DCtoZones"
Range(.Offset(m, 1), .Offset(m, 1)).Select
With Selection.Interior
.ColorIndex = 5
.Pattern = xlSolid
End With
Selection.Merge

.Offset(m + 1, 0) = "DC"
z = 0
For i = 1 To nZones
If isSelectedZone(i) Then
z = z + 1
.Offset(m + 1, z) = ZoneList(i)
End If
Next
z = 0
For i = 1 To nDCs
If isSelectedDC(i) Then
z = z + 1
.Offset(m + 1 + z, 0) = DCList(i)
End If
Next
k = m + 1
        '
' Enter all data from worksheet COST TO ZONES * DISTANCE TO ZONES
        '
For j = 1 To nDCs
```

```
If isSelectedDC(j) Then
k = k + 1
ZoneI = 0

For i = 1 To nZones
If isSelectedZone(i) Then
ZoneI = ZoneI + 1
' Enter formula of cost to zones * distance to zones
.Offset(k, ZoneI).FormulaR1C1 = "=" & Worksheets("COST TO ZONES").Range("costanchor_3").Offset(j, i).Value _
& "*" & Worksheets("DISTANCE TO ZONES").Range("distanceanchor_3").Offset(j, i).Value
End If
Next
End If
Next
k = m
Range(.Offset(m + 2, 1), .Offset(m + 2, 1).End(xlDown).End(xlToRight)).Name = "DCZone_Cost"
Range(.Offset(m + 2, 1), .Offset(m + 2, 1).End(xlDown).End(xlToRight)).Select
Selection.NumberFormat = "0"
With Selection.Interior
.ColorIndex = 4
.Pattern = xlSolid
End With

' Obtain the last row and skip a row to start next table
m = Range(.Offset(m, 1), .Offset(m, 1).End(xlDown)).Count
k = k + m + 1
m = k


' Display headings of Tariffs and Duties - Plant to Warehouse
.Offset(m, 1) = "Tariffs and Duties"
Range(.Offset(m, 1), .Offset(m, 1)).Select
With Selection.Interior
.ColorIndex = 27
.Pattern = xlSolid
End With
Selection.Merge

.Offset(m + 1, 0) = "Plant"
z = 0
For i = 1 To nWarehouses
If isSelectedWarehouse(i) Then
z = z + 1
.Offset(m + 1, z) = warehouseList(i)
End If
Next
z = 0
For i = 1 To nPlants
If isSelectedPlant(i) Then
z = z + 1
.Offset(m + 1 + z, 0) = plantList(i)
End If
Next
k = m + 1
plantI = 0
          '
' Enter all data from PRICE TRANSFER * TARIFFS % - Plant to Warehouse
        '
For j = 1 To nPlants
If isSelectedPlant(j) Then
k = k + 1
warehouseI = 0

For i = 1 To nWarehouses
If isSelectedWarehouse(i) Then
warehouseI = warehouseI + 1
' Enter formula of price transfer * tariffs
.Offset(k, warehouseI).FormulaR1C1 = "=R[-" & m + plantI - 1 & "]C[" & plantI + 1 - warehouseI & "]" _
```

```
& “*R[-“ & m + plantI - 16 & “]C” & “*” & 10


End If
Next
plantI = plantI + 1
End If
Next
k = m
Range(.Offset(m + 2, 1), .Offset(m + 2, 1).End(xlDown).End(xlToRight)).Name = “PlantWarehouse_Tariffs”
Range(.Offset(m + 2, 1), .Offset(m + 2, 1).End(xlDown).End(xlToRight)).Select
Selection.NumberFormat = “0”
With Selection.Interior
.ColorIndex = 29
.Pattern = xlSolid
End With

‘ Obtain the last row and skip a row to start next table
m = Range(.Offset(m, 1), .Offset(m, 1).End(xlDown)).Count
k = k + m + 1
m = k


‘ Display headings of Tariffs and Duties - Warehouse to DC
.Offset(m, 1) = “Tariffs and Duties”
Range(.Offset(m, 1), .Offset(m, 1)).Select
With Selection.Interior
.ColorIndex = 27
.Pattern = xlSolid
End With
Selection.Merge

.Offset(m + 1, 0) = “Warehouse”
z = 0
For i = 1 To nDCs
If isSelectedDC(i) Then
z = z + 1
.Offset(m + 1, z) = DCList(i)
End If
Next
z = 0
For i = 1 To nWarehouses
If isSelectedWarehouse(i) Then
z = z + 1
.Offset(m + 1 + z, 0) = warehouseList(i)
End If
Next
k = m + 1
warehouseI = 0
        ‘
‘ Enter all data from PRICE TRANSFER * TARIFFS % - Warehouse to DC
      ‘
For j = 1 To nWarehouses
If isSelectedWarehouse(j) Then
k = k + 1
DCI = 0

For i = 1 To nDCs
If isSelectedDC(i) Then
DCI = DCI + 1
‘ Enter formula of price transfer * tariffs
.Offset(k, DCI).FormulaR1C1 = “=R[-“ & m + warehouseI - 14 & “]C[” & warehouseI + 1 - DCI & “]” _
& “*R[-“ & m + warehouseI - plantIndex - 31 & “]C” & “*” & 10
End If
Next
warehouseI = warehouseI + 1
End If
Next
k = m
```

```
Range(.Offset(m + 2, 1), .Offset(m + 2, 1).End(xlDown).End(xlToRight)).Name = "WarehouseDC_Tariffs"
Range(.Offset(m + 2, 1), .Offset(m + 2, 1).End(xlDown).End(xlToRight)).Select
Selection.NumberFormat = "0"
With Selection.Interior
.ColorIndex = 29
.Pattern = xlSolid
End With

' Obtain the last row and skip a row to start next table
m = Range(.Offset(m, 1), .Offset(m, 1).End(xlDown)).Count
k = k + m + 1
m = k


' THESE ROUTINES ARE TO DISPLAY y-BINARY MAX CAPACITY
' Display headings of Maximum Capacity table - Plant to Warehouse
.Offset(m, 1) = "Maximum Capacity - Y"
Range(.Offset(m, 1), .Offset(m, 1)).Select
With Selection.Interior
.ColorIndex = 16
.Pattern = xlSolid
End With
Selection.Merge

.Offset(m + 1, 0) = "Plant"
z = 0
For i = 1 To nWarehouses
If isSelectedWarehouse(i) Then
z = z + 1
.Offset(m + 1, z) = warehouseList(i)
End If
Next
z = 0
For i = 1 To nPlants
If isSelectedPlant(i) Then
z = z + 1
.Offset(m + 1 + z, 0) = plantList(i)
End If
Next
k = m + 1
plantI = 0
        '
' Enter all data from worksheet CAPACITY TO WAREHOUSES
        '
For j = 1 To nPlants
If isSelectedPlant(j) Then
k = k + 1
warehouseI = 0

For i = 1 To nWarehouses
If isSelectedWarehouse(i) Then
warehouseI = warehouseI + 1
' Enter formula of maximum capacity * plant binary
.Offset(k, warehouseI).FormulaR1C1 = "=" & Worksheets("CAPACITY TO
WAREHOUSES").Range("capacityanchor_1").Offset(j, i).Value _
& "*R[-" & m + plantI - 6 & "]C[" & plantI + 1 - warehouseI & "]"
End If
Next
plantI = plantI + 1
End If
Next
k = m
Range(.Offset(m + 2, 1), .Offset(m + 2, 1).End(xlDown).End(xlToRight)).Name = "PlantWarehouse_MaxCapacity"
Range(.Offset(m + 2, 1), .Offset(m + 2, 1).End(xlDown).End(xlToRight)).Select
Selection.NumberFormat = "0"
With Selection.Interior
.ColorIndex = 15
```

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```
.Pattern = xlSolid
End With

' Obtain the last row and skip a row to start next table
m = Range(.Offset(m, 1), .Offset(m, 1).End(xlDown)).Count
k = k + m + 1
m = k


' Display headings of Maximum Capacity table - Warehouse to DC
.Offset(m, 1) = "Maximum Capacity - Y"
Range(.Offset(m, 1), .Offset(m, 1)).Select
With Selection.Interior
.ColorIndex = 16
.Pattern = xlSolid
End With
Selection.Merge

.Offset(m + 1, 0) = "Warehouse"
z = 0
For i = 1 To nDCs
If isSelectedDC(i) Then
z = z + 1
.Offset(m + 1, z) = DCList(i)
End If
Next
z = 0
For i = 1 To nWarehouses
If isSelectedWarehouse(i) Then
z = z + 1
.Offset(m + 1 + z, 0) = warehouseList(i)
End If
Next
k = m + 1
warehouseI = 0
        '
' Enter all data from worksheet CAPACITY TO DCs
        '
For j = 1 To nWarehouses
If isSelectedWarehouse(j) Then
k = k + 1
DCI = 0

For i = 1 To nDCs
If isSelectedDC(i) Then
DCI = DCI + 1
' Enter formula of maximum capacity * plant binary
.Offset(k, DCI).FormulaR1C1 = "=" & Worksheets("CAPACITY TO DCs").Range("capacityanchor_2").Offset(j, i).Value _
& "*R[-" & m + warehouseI - 20 & "]C[" & warehouseI + 1 - DCI & "]"
End If
Next
warehouseI = warehouseI + 1
End If
Next
k = m
Range(.Offset(m + 2, 1), .Offset(m + 2, 1).End(xlDown).End(xlToRight)).Select
Selection.NumberFormat = "0"
With Selection.Interior
.ColorIndex = 15
.Pattern = xlSolid
End With

' Name the Max Capacity Matrix - Warehouse to DC
Range(.Offset(m + 2, 1), .Offset(m + 2, 1).End(xlDown).End(xlToRight)).Name = "WarehouseDC_MaxCapacity"
' Obtain the last row and skip a row to start next table
m = Range(.Offset(m, 1), .Offset(m, 1).End(xlDown)).Count
k = k + m + 1
m = k
```

```
' Display headings of Maximum Capacity table - DC to Zones
.Offset(m, 1) = "Maximum Capacity - Y"
Range(.Offset(m, 1), .Offset(m, 1)).Select
With Selection.Interior
.ColorIndex = 16
.Pattern = xlSolid
End With
Selection.Merge

.Offset(m + 1, 0) = "DC"
z = 0
For i = 1 To nZones
If isSelectedZone(i) Then
z = z + 1
.Offset(m + 1, z) = ZoneList(i)
End If
Next
z = 0
For i = 1 To nDCs
If isSelectedDC(i) Then
z = z + 1
.Offset(m + 1 + z, 0) = DCList(i)
End If
Next
k = m + 1
DCI = 0
        '
' Enter all data from worksheet CAPACITY TO DCs
        '
For j = 1 To nDCs
If isSelectedDC(j) Then
k = k + 1
ZoneI = 0

For i = 1 To nZones
If isSelectedZone(i) Then
ZoneI = ZoneI + 1
' Enter formula of maximum capacity * plant binary
.Offset(k, ZoneI).FormulaR1C1 = "=" & Worksheets("CAPACITY TO ZONES").Range("capacityanchor_3").Offset(j, i).Value _
& "*R[-" & m + DCI - plantIndex - 35 & "]C[" & DCI + 1 - ZoneI & "]"
End If
Next
DCI = DCI + 1
End If
Next
k = m
Range(.Offset(m + 2, 1), .Offset(m + 2, 1).End(xlDown).End(xlToRight)).Select
Selection.NumberFormat = "0"
With Selection.Interior
.ColorIndex = 15
.Pattern = xlSolid
End With

' Name the Max Capacity Matrix - DC to Zone
Range(.Offset(m + 2, 1), .Offset(m + 2, 1).End(xlDown).End(xlToRight)).Name = "DCZone_MaxCapacity"
' Obtain the last row and skip a row to start next table
m = Range(.Offset(m, 1), .Offset(m, 1).End(xlDown)).Count
k = k + m + 1
m = k

End With
Range("A1").Select
End Sub
Sub CalcMonetaryValues()
' This sub calculates the summary monetary values.
With Range("ObjectiveFunction")
```

```
.Offset(0, 0).Formula = "=Sumproduct(CostUnit,PlantDV) + Sumproduct(PlantBinary,PlantFixedCost)+
Sumproduct(WarehouseBinary,WarehouseFixedCost)+ Sumproduct(DCBinary,DCFixedCost)+
Sumproduct(Sum1_Warehouses,WarehouseHandlingCost)+ Sumproduct(Sum1_DCs,DCHandlingCost)+
Sumproduct(PlantBinary,PlantFixedCost,PlantFreedom)+
Sumproduct(WarehouseBinary,WarehouseFixedCost,WarehouseFreedom)+ Sumproduct(DCBinary,DCFixedCost,DCFreedom)+
Sumproduct(PlantWarehouseDV,PlantWarehouse_Cost)+ Sumproduct(WarehouseDCDV,WarehouseDC_Cost)+
Sumproduct(DCZoneDV,DCZone_Cost)+ Sumproduct(PlantWarehouseDV,PlantWarehouse_Tariffs)+
Sumproduct(WarehouseDCDV,WarehouseDC_Tariffs)+ Sumproduct(PlantWarehouseDV_X,PlantWarehouse_LeadTime)+
Sumproduct(WarehouseDCDV_X,WarehouseDC_LeadTime)+ Sumproduct(DCZoneDV_X,DCZone_LeadTime)"
End With
End Sub
Sub RunSolver()
' This sub sets up and runs Solver.
Dim solverStatus As Integer
Dim prob As New Problem
Dim Plants_Fixed As Variant

Plants_Fixed = Range("fixedplants")
' Reset Solver settings, then set up Solver.
SolverReset

'pick an engine
prob.Engine = prob.Engines("Standard LP/Quadratic")
' set a parameter
prob.Engine.Params("AssumeNonNeg").Value = 1

' Add objective function and DVs (Fixed Network or not)
If Plants_Fixed = "YES" Then
SolverOK SetCell:=Range("ObjectiveFunction"), MaxMinVal:=2,
ByChange:=Range("PlantDV,PlantWarehouseDV,WarehouseDCDV,DCZoneDV,PlantWarehouseDV_X,WarehouseDCDV_X,
DCZoneDV_X")
Else
SolverOK SetCell:=Range("ObjectiveFunction"), MaxMinVal:=2,
ByChange:=Range("PlantDV,PlantBinary,PlantWarehouseDV,WarehouseBinary,WarehouseDCDV,DCBinary,DCZoneDV,Plant
WarehouseDV_X,WarehouseDCDV_X,DCZoneDV_X")
' Add constraints that go along with the Objective Function
SolverAdd CellRef:="PlantBinary", Relation:=5, FormulaText:="binary", Comment:=""
SolverAdd CellRef:="WarehouseBinary", Relation:=5, FormulaText:="binary", Comment:=""
SolverAdd CellRef:="DCBinary", Relation:=5, FormulaText:="binary", Comment:=""
End If
' Add Integer parameters
SolverIntOptions MaxSubproblems:=5000, MaxIntegerSols:=5000, IntTolerance:=0.05 _
, SolveWithout:=False, MaxRootCutPasses:=-1, MaxTreeCutPasses:=100, _
StrongBranching:=True, LiftAndCoverCuts:=False, RoundingCuts:=False, _
KnapsackCuts:=True
SolverIntOptions GomoryCuts:=False, ProbingCuts:=True, OddHoleCuts:=False, _
CliqueCuts:=False, FlowCoverCuts:=False, MirCuts:=True, TwoMirCuts:=False, _
RoundingHeur:=True, LocalHeur:=False, RedSplitCuts:=False, SOSCuts:=False
' Add constraints.
SolverAdd CellRef:="PlantWarehouseDV_X", Relation:=5, FormulaText:="binary", Comment:=""
SolverAdd CellRef:="WarehouseDCDV_X", Relation:=5, FormulaText:="binary", Comment:=""
SolverAdd CellRef:="DCZonesDV_X", Relation:=5, FormulaText:="binary", Comment:=""
SolverAdd CellRef:="PlantDV", Relation:=3, FormulaText:="PlantMin", Comment:=""
SolverAdd CellRef:="PlantDV", Relation:=1, FormulaText:="PlantMax", Comment:=""
SolverAdd CellRef:="Sum1_Warehouses", Relation:=3, FormulaText:="WarehouseMin", Comment:=""
SolverAdd CellRef:="Sum1_Warehouses", Relation:=1, FormulaText:="WarehouseMax", Comment:=""
SolverAdd CellRef:="Sum1_DCs", Relation:=3, FormulaText:="DCMin", Comment:=""
SolverAdd CellRef:="Sum1_DCs", Relation:=1, FormulaText:="DCMax", Comment:=""
SolverAdd CellRef:="PlantDV", Relation:=3, FormulaText:="0", Comment:=""
SolverAdd CellRef:="PlantWarehouseDV", Relation:=3, FormulaText:="0", Comment:=""
SolverAdd CellRef:="WarehouseDCDV", Relation:=3, FormulaText:="0", Comment:=""
SolverAdd CellRef:="DCZonesDV", Relation:=3, FormulaText:="0", Comment:=""
SolverAdd CellRef:="PlantDV", Relation:=2, FormulaText:="Sum_Plants", Comment:=""
SolverAdd CellRef:="Sum1_Warehouses", Relation:=2, FormulaText:="Sum2_Warehouses", Comment:=""
SolverAdd CellRef:="Sum1_DCs", Relation:=2, FormulaText:="Sum2_DCs", Comment:=""
SolverAdd CellRef:="Sum1_Zones", Relation:=2, FormulaText:="CustomerDemand", Comment:=""
SolverAdd CellRef:="PlantWarehouseDV", Relation:=1, FormulaText:="PlantWarehouse_MaxCapacityX", Comment:=""
SolverAdd CellRef:="WarehouseDCDV", Relation:=1, FormulaText:="WarehouseDC_MaxCapacityX", Comment:=""
```

```
SolverAdd CellRef:="DCZonesDV", Relation:=1, FormulaText:="DCZone_MaxCapacityX", Comment:=""
'    SolverAdd CellRef:="PlantWarehouseDV", Relation:=1, FormulaText:="PlantWarehouse_MaxCapacity", Comment:=""
'    SolverAdd CellRef:="WarehouseDCDV", Relation:=1, FormulaText:="WarehouseDC_MaxCapacity", Comment:=""
'    SolverAdd CellRef:="DCZonesDV", Relation:=1, FormulaText:="DCZone_MaxCapacity", Comment:=""

    SolverAdd CellRef:="PlantWarehouseDV_X", Relation:=1, FormulaText:="PlantWarehouse_Y", Comment:=""
    SolverAdd CellRef:="PlantWarehouseDV_X", Relation:=1, FormulaText:="PlantWarehouse_Y2", Comment:=""
    SolverAdd CellRef:="WarehouseDCDV_X", Relation:=1, FormulaText:="WarehouseDC_Y", Comment:=""
    SolverAdd CellRef:="WarehouseDCDV_X", Relation:=1, FormulaText:="WarehouseDC_Y2", Comment:=""
    SolverAdd CellRef:="DCZonesDV_X", Relation:=1, FormulaText:="DCZone_Y", Comment:=""


    ' Run Solver and check for infeasibility.
    solverStatus = SolverSolve(UserFinish:=True)

    If solverStatus = 5 Then
        ' There is no feasible solution, so report this, tidy up, and quit.
        MsgBox "This model has no feasible solution. Change the data " _
            & "in the Data sheet and try running it again.", _
            vbInformation, "No feasible solution"
        Call Charts
        Worksheets("Menu").Activate
        Range("A1").Select
'       Worksheets("Model").Visible = False
'       Worksheets("Report").Visible = False
        End
    End If
End Sub

Sub Charts()

    ' This sub changes the range names of all charts
    Sheets("Chart1").Select
    ActiveChart.PlotArea.Select
    ActiveChart.SetSourceData Source:=Sheets("MODEL").Range("PlantWarehouseDV_G"), PlotBy:=xlRows
    ActiveChart.Deselect

    Sheets("Chart2").Select
    ActiveChart.PlotArea.Select
    ActiveChart.SetSourceData Source:=Sheets("MODEL").Range("WarehouseDCDV_G"), PlotBy:=xlRows
    ActiveChart.Deselect

    Sheets("Chart3").Select
    ActiveChart.PlotArea.Select
    ActiveChart.SetSourceData Source:=Sheets("MODEL").Range("DCZonesDV_G"), PlotBy:=xlRows
    ActiveChart.Deselect

    Worksheets("Menu").Activate
    Range("A1").Select
    End


End Sub


Sub CreateReport()
    ' This sub fills in the Report sheet, mostly by transferring the results from the Model sheet.
    Dim i As Integer

    ' Hide Model sheet.
    Worksheets("Model").Visible = False

    ' Unhide and activate Report sheet.
    With Worksheets("Report")
        .Visible = True
        .Activate
    End With
```

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    ' Enter results in three steps.
    Call EnterMonetaryResults
    Call EnterProductResults
    Call EnterResourceResults

    ' Make sure columns C and I are wide enough, then select cell A1.
    Columns("C:C").Columns.AutoFit
    Columns("I:I").Columns.AutoFit
    Range("A1").Select
End Sub

Sub EnterMonetaryResults()
    ' This sub transfers the total revenue, total cost, and total profit.
    Dim i As Integer
    With Range("C4")
        For i = 1 To 3
            .Offset(i, 0) = Range("MonSummAnchor").Offset(i, 1)
        Next
    End With

End Sub

Sub EnterProductResults()
    ' This sub transfers results for the products in the optimal product mix.
    Dim productIndex As Integer
    Dim i As Integer

    With Range("ProdRepAnchor")
        ' Clear old data (if any).
        Range(.Offset(1, 0), .Offset(1, 0).End(xlDown).End(xlToRight)) _
            .ClearContents

        ' Enter results for selected products only, where productIndex is a counter for these.
        productIndex = 0
        For i = 1 To nProducts
            If isSelected(i) Then
                productIndex = productIndex + 1

                ' Enter product code, description, and number of units produced.
                .Offset(productIndex, 0) = Range("ProdAnchor").Offset(i, 0)
                .Offset(productIndex, 1) = Range("ProdAnchor").Offset(i, 1)
                .Offset(productIndex, 2) = Range("Produced").Cells(productIndex)

                ' Calculate revenue, cost, and profit for the product.
                .Offset(productIndex, 3) = Range("Produced").Cells(productIndex) * _
Range("UnitRev").Cells(productIndex)
.Offset(productIndex, 4) = Range("Produced").Cells(productIndex) * _
Range("UnitCost").Cells(productIndex)
.Offset(productIndex, 5) = Range("Produced").Cells(productIndex) * _
Range("UnitProfit").Cells(productIndex)
End If
Next
End With
End Sub
Sub EnterResourceResults()
' This sub transfers results about resource usage.
Dim i As Integer
With Range("ResRepAnchor")
' Clear old data (if any).
Range(.Offset(1, 0), .Offset(1, 0).End(xlDown).End(xlToRight)).ClearContents
For i = 1 To nResources

' Enter resource name, amount used, and amount available.
.Offset(i, 0) = Range("ResAnchor").Offset(i, 0)
.Offset(i, 1) = Range("Used").Cells(i)
.Offset(i, 2) = Range("Available").Cells(i)

' Calculate amount left over.
```

```
.Offset(i, 3).FormulaR1C1 = "=RC[-1]-RC[-2]"
Next
End With
End Sub
Sub ReRunModel()
Dim prob As New Problem
'pick an engine
prob.Engine = prob.Engines("Standard LP/Quadratic")
' set a parameter
prob.Engine.Params("AssumeNonNeg").Value = 1

prob.Solver.Optimize
End Sub
Sub PlanttoWarehouseCapacity()
' This sub creates the headings for the Plant to Warehouse matrix - Capacity
Dim i As Integer, z As Integer

' Get the lists of warehouses and plants.
Call GetPlants
Call Getwarehouses

Worksheets("Capacity To Warehouses").Activate
' Displays the warehouses and plants on the matrix.
With Range("capacityanchor_1")
z = 0
For i = 1 To nWarehouses
z = z + 1
.Offset(0, z) = warehouseList(i)
Next
z = 0
For i = 1 To nPlants
z = z + 1
.Offset(z, 0) = plantList(i)
Next


If nWarehouses = 0 Or nPlants = 0 Then
MsgBox "There is not enough facilities. There is only " & nPlants & " plants and " & _
nWarehouses & " warehouses in the system", vbExclamation, "Infeasible"
End
Else
Range("A1").Select
ActiveSheet.ShowDataForm
End If
End With
End Sub
Sub WarehousetoDCCapacity()
' This sub creates the headings for the Warehouse to DC matrix - Capacity
Dim i As Integer, z As Integer

' Get the lists of warehouses and DCs.
Call GetDCs
Call Getwarehouses

Worksheets("Capacity To DCs").Activate
' Displays the warehouses and DCs on the matrix.
With Range("capacityanchor_2")
z = 0
For i = 1 To nDCs
z = z + 1
.Offset(0, z) = DCList(i)
Next
z = 0
For i = 1 To nWarehouses
z = z + 1
.Offset(z, 0) = warehouseList(i)
Next
```

```
If nWarehouses = 0 Or nDCs = 0 Then
MsgBox "There is not enough facilities. There is only " & nDCs & " DCs and " & _
nWarehouses & " warehouses in the system", vbExclamation, "Infeasible"
Worksheets("Menu1").Activate
End
Else
Range("A1").Select
ActiveSheet.ShowDataForm
End If
End With
End Sub
Sub DCtoZoneCapacity()
' This sub creates the headings for the DC to Zone matrix - Capacity
Dim i As Integer, z As Integer

' Get the lists of DCs and Zones.
Call GetDCs
Call GetZones

Worksheets("Capacity to Zones").Activate
' Displays the DCs and Zones on the matrix.
With Range("capacityanchor_3")
z = 0
For i = 1 To nZones
z = z + 1
.Offset(0, z) = ZoneList(i)
Next
z = 0
For i = 1 To nDCs
z = z + 1
.Offset(z, 0) = DCList(i)
Next

If nZones = 0 Or nDCs = 0 Then
MsgBox "There is not enough facilities. There is only " & nDCs & " DCs and " & _
nZones & " zones in the system", vbExclamation, "Infeasible"
Worksheets("Menu1").Activate
End
Else
Range("A1").Select
ActiveSheet.ShowDataForm
End If
End With
End Sub
Sub PlanttoWarehouseCost()
' This sub creates the headings for the Plant to Warehouse matrix - Cost
Dim i As Integer, z As Integer

' Get the lists of warehouses and plants.
Call GetPlants
Call Getwarehouses

Worksheets("Cost To Warehouses").Activate
' Displays the warehouses and plants on the matrix.
With Range("costanchor_1")
z = 0
For i = 1 To nWarehouses
z = z + 1
.Offset(0, z) = warehouseList(i)
Next
z = 0
For i = 1 To nPlants
z = z + 1
.Offset(z, 0) = plantList(i)
Next


If nWarehouses = 0 Or nPlants = 0 Then
```

```
MsgBox "There is not enough facilities. There is only " & nPlants & " plants and " & _
nWarehouses & " warehouses in the system", vbExclamation, "Infeasible"
End
Else
Range("A1").Select
ActiveSheet.ShowDataForm
End If
End With
End Sub
Sub WarehousetoDCCost()
' This sub creates the headings for the Warehouse to DC matrix - Cost
Dim i As Integer, z As Integer

' Get the lists of warehouses and DCs.
Call GetDCs
Call Getwarehouses

Worksheets("Cost To DCs").Activate
' Displays the warehouses and DCs on the matrix.
With Range("costanchor_2")
z = 0
For i = 1 To nDCs
z = z + 1
.Offset(0, z) = DCList(i)
Next
z = 0
For i = 1 To nWarehouses
z = z + 1
.Offset(z, 0) = warehouseList(i)
Next

If nWarehouses = 0 Or nDCs = 0 Then
MsgBox "There is not enough facilities. There is only " & nDCs & " DCs and " & _
nWarehouses & " warehouses in the system", vbExclamation, "Infeasible"
Worksheets("Menu1").Activate
End
Else
Range("A1").Select
ActiveSheet.ShowDataForm
End If
End With
End Sub
Sub DCtoZoneCost()
' This sub creates the headings for the DC to Zone matrix - Cost
Dim i As Integer, z As Integer

' Get the lists of DCs and Zones.
Call GetDCs
Call GetZones

Worksheets("Cost to Zones").Activate
' Displays the DCs and Zones on the matrix.
With Range("costanchor_3")
z = 0
For i = 1 To nZones
z = z + 1
.Offset(0, z) = ZoneList(i)
Next
z = 0
For i = 1 To nDCs
z = z + 1
.Offset(z, 0) = DCList(i)
Next

If nZones = 0 Or nDCs = 0 Then
MsgBox "There is not enough facilities. There is only " & nDCs & " DCs and " & _
nZones & " zones in the system", vbExclamation, "Infeasible"
Worksheets("Menu1").Activate
```

```
End
Else
Range("A1").Select
ActiveSheet.ShowDataForm
End If
End With
End Sub
Sub PlanttoWarehouseDistance()
' This sub creates the headings for the Plant to Warehouse matrix - Distance
Dim i As Integer, z As Integer

' Get the lists of warehouses and plants.
Call GetPlants
Call Getwarehouses

Worksheets("Distance To Warehouses").Activate
' Displays the warehouses and plants on the matrix.
With Range("distanceanchor_1")
z = 0
For i = 1 To nWarehouses
z = z + 1
.Offset(0, z) = warehouseList(i)
Next
z = 0
For i = 1 To nPlants
z = z + 1
.Offset(z, 0) = plantList(i)
Next


If nWarehouses = 0 Or nPlants = 0 Then
MsgBox "There is not enough facilities. There is only " & nPlants & " plants and " & _
nWarehouses & " warehouses in the system", vbExclamation, "Infeasible"
End
Else
Range("A1").Select
ActiveSheet.ShowDataForm
End If
End With
End Sub
Sub WarehousetoDCDistance()
' This sub creates the headings for the Warehouse to DC matrix - Distance
Dim i As Integer, z As Integer

' Get the lists of warehouses and DCs.
Call GetDCs
Call Getwarehouses

Worksheets("Distance To DCs").Activate
' Displays the warehouses and DCs on the matrix.
With Range("distanceanchor_2")
z = 0
For i = 1 To nDCs
z = z + 1
.Offset(0, z) = DCList(i)
Next
z = 0
For i = 1 To nWarehouses
z = z + 1
.Offset(z, 0) = warehouseList(i)
Next

If nWarehouses = 0 Or nDCs = 0 Then
MsgBox "There is not enough facilities. There is only " & nDCs & " DCs and " & _
nWarehouses & " warehouses in the system", vbExclamation, "Infeasible"
Worksheets("Menu1").Activate
End
Else
```

```
Range("A1").Select
ActiveSheet.ShowDataForm
End If
End With
End Sub
Sub DCtoZoneDistance()
' This sub creates the headings for the DC to Zone matrix - Distance
Dim i As Integer, z As Integer

' Get the lists of DCs and Zones.
Call GetDCs
Call GetZones

Worksheets("Distance to Zones").Activate
' Displays the DCs and Zones on the matrix.
With Range("distanceanchor_3")
z = 0
For i = 1 To nZones
z = z + 1
.Offset(0, z) = ZoneList(i)
Next
z = 0
For i = 1 To nDCs
z = z + 1
.Offset(z, 0) = DCList(i)
Next

If nZones = 0 Or nDCs = 0 Then
MsgBox "There is not enough facilities. There is only " & nDCs & " DCs and " & _
nZones & " zones in the system", vbExclamation, "Infeasible"
Worksheets("Menu1").Activate
End
Else
Range("A1").Select
ActiveSheet.ShowDataForm
End If
End With
End Sub
Sub PlanttoWarehouseLeadTime()
' This sub creates the headings for the Plant to Warehouse matrix - Lead Time
Dim i As Integer, z As Integer

' Get the lists of warehouses and plants.
Call GetPlants
Call Getwarehouses

Worksheets("LeadTime To Warehouses").Activate
' Displays the warehouses and plants on the matrix.
With Range("leadtimeanchor_1")
z = 0
For i = 1 To nWarehouses
z = z + 1
.Offset(0, z) = warehouseList(i)
Next
z = 0
For i = 1 To nPlants
z = z + 1
.Offset(z, 0) = plantList(i)
Next


If nWarehouses = 0 Or nPlants = 0 Then
MsgBox "There is not enough facilities. There is only " & nPlants & " plants and " & _
nWarehouses & " warehouses in the system", vbExclamation, "Infeasible"
End
Else
Range("A1").Select
ActiveSheet.ShowDataForm
```

```
End If
End With
End Sub
Sub WarehousetoDCLeadTime()
' This sub creates the headings for the Warehouse to DC matrix - Lead Time
Dim i As Integer, z As Integer

' Get the lists of warehouses and DCs.
Call GetDCs
Call Getwarehouses

Worksheets("LeadTime To DCs").Activate
' Displays the warehouses and DCs on the matrix.
With Range("leadtimeanchor_2")
z = 0
For i = 1 To nDCs
z = z + 1
.Offset(0, z) = DCList(i)
Next
z = 0
For i = 1 To nWarehouses
z = z + 1
.Offset(z, 0) = warehouseList(i)
Next

If nWarehouses = 0 Or nDCs = 0 Then
MsgBox "There is not enough facilities. There is only " & nDCs & " DCs and " & _
nWarehouses & " warehouses in the system", vbExclamation, "Infeasible"
Worksheets("Menu1").Activate
End
Else
Range("A1").Select
ActiveSheet.ShowDataForm
End If
End With
End Sub
Sub DCtoZoneLeadTime()
' This sub creates the headings for the DC to Zone matrix - Lead Time
Dim i As Integer, z As Integer

' Get the lists of DCs and Zones.
Call GetDCs
Call GetZones

Worksheets("LeadTime to Zones").Activate
' Displays the DCs and Zones on the matrix.
With Range("leadtimeanchor_3")
z = 0
For i = 1 To nZones
z = z + 1
.Offset(0, z) = ZoneList(i)
Next
z = 0
For i = 1 To nDCs
z = z + 1
.Offset(z, 0) = DCList(i)
Next

If nZones = 0 Or nDCs = 0 Then
MsgBox "There is not enough facilities. There is only " & nDCs & " DCs and " & _
nZones & " zones in the system", vbExclamation, "Infeasible"
Worksheets("Menu1").Activate
End
Else
Range("A1").Select
ActiveSheet.ShowDataForm
End If
End With
```

```vba
End Sub
Sub Form_Data()
' This sub opens the form to add/change any data
Range("A2").Select
ActiveSheet.ShowDataForm

End Sub
Sub Add_Change_Data_1a()
' This sub opens the form to add/change data - capacity plants to warehouses
Call GetPlants
Call Getwarehouses

Worksheets("Capacity To Warehouses").Activate
If nWarehouses = 0 Or nPlants = 0 Then
MsgBox "There is not enough facilities. There is only " & nPlants & " plants and " & _
nWarehouses & " warehouses in the system", vbExclamation, "Infeasible"
Worksheets("Menu1").Activate
End
Else
Range("A1").Select
ActiveSheet.ShowDataForm
End If
End Sub
Sub Add_Change_Data_2a()
' This sub opens the form to add/change data - capacity warehouses to DCS
Call GetDCs
Call Getwarehouses

Worksheets("Capacity To DCs").Activate
If nWarehouses = 0 Or nDCs = 0 Then
MsgBox "There is not enough facilities. There is only " & nWarehouses & " warehouses and " & _
nDCs & " DCs in the system", vbExclamation, "Infeasible"
Worksheets("Menu1").Activate
End
Else
Range("A1").Select
ActiveSheet.ShowDataForm
End If
End Sub
Sub Add_Change_Data_3a()
' This sub opens the form to add/change data - capacity DCs to Zones
Call GetDCs
Call GetZones

Worksheets("Capacity To Zones").Activate
If nZones = 0 Or nDCs = 0 Then
MsgBox "There is not enough facilities. There is only " & nDCs & " DCs and " & _
nZones & " zones in the system", vbExclamation, "Infeasible"
Worksheets("Menu1").Activate
End
Else
Range("A1").Select
ActiveSheet.ShowDataForm
End If
End Sub
Sub Add_Change_Data_1b()
' This sub opens the form to add/change data - cost plants to warehouses
Call GetPlants
Call Getwarehouses

Worksheets("Cost To Warehouses").Activate
If nWarehouses = 0 Or nPlants = 0 Then
MsgBox "There is not enough facilities. There is only " & nPlants & " plants and " & _
nWarehouses & " warehouses in the system", vbExclamation, "Infeasible"
Worksheets("Menu1").Activate
End
Else
Range("A1").Select
```

```
ActiveSheet.ShowDataForm
End If
End Sub
Sub Add_Change_Data_2b()
' This sub opens the form to add/change data - cost warehouses to DCS
Call GetDCs
Call Getwarehouses

Worksheets("Cost To DCs").Activate
If nWarehouses = 0 Or nDCs = 0 Then
MsgBox "There is not enough facilities. There is only " & nWarehouses & " warehouses and " & _
nDCs & " DCs in the system", vbExclamation, "Infeasible"
Worksheets("Menu1").Activate
End
Else
Range("A1").Select
ActiveSheet.ShowDataForm
End If
End Sub
Sub Add_Change_Data_3b()
' This sub opens the form to add/change data - cost DCs to Zones
Call GetDCs
Call GetZones

Worksheets("Cost To Zones").Activate
If nZones = 0 Or nDCs = 0 Then
MsgBox "There is not enough facilities. There is only " & nDCs & " DCs and " & _
nZones & " zones in the system", vbExclamation, "Infeasible"
Worksheets("Menu1").Activate
End
Else
Range("A1").Select
ActiveSheet.ShowDataForm
End If
End Sub
Sub Add_Change_Data_1c()
' This sub opens the form to add/change data - lead time plants to warehouses
Call GetPlants
Call Getwarehouses

Worksheets("LeadTime To Warehouses").Activate
If nWarehouses = 0 Or nPlants = 0 Then
MsgBox "There is not enough facilities. There is only " & nPlants & " plants and " & _
nWarehouses & " warehouses in the system", vbExclamation, "Infeasible"
Worksheets("Menu1").Activate
End
Else
Range("A1").Select
ActiveSheet.ShowDataForm
End If
End Sub
Sub Add_Change_Data_2c()
' This sub opens the form to add/change data - lead time warehouses to DCS
Call GetDCs
Call Getwarehouses

Worksheets("LeadTime To DCs").Activate
If nWarehouses = 0 Or nDCs = 0 Then
MsgBox "There is not enough facilities. There is only " & nWarehouses & " warehouses and " & _
nDCs & " DCs in the system", vbExclamation, "Infeasible"
Worksheets("Menu1").Activate
End
Else
Range("A1").Select
ActiveSheet.ShowDataForm
End If
End Sub
Sub Add_Change_Data_3c()
```

```
' This sub opens the form to add/change data - lead time DCs to Zones
Call GetDCs
Call GetZones

Worksheets("LeadTime To Zones").Activate
If nZones = 0 Or nDCs = 0 Then
MsgBox "There is not enough facilities. There is only " & nDCs & " DCs and " & _
nZones & " zones in the system", vbExclamation, "Infeasible"
Worksheets("Menu1").Activate
End
Else
Range("A1").Select
ActiveSheet.ShowDataForm
End If
End Sub
Sub Add_Change_Data_1d()
' This sub opens the form to add/change data - distance plants to warehouses
Call GetPlants
Call Getwarehouses

Worksheets("Distance To Warehouses").Activate
If nWarehouses = 0 Or nPlants = 0 Then
MsgBox "There is not enough facilities. There is only " & nPlants & " plants and " & _
nWarehouses & " warehouses in the system", vbExclamation, "Infeasible"
Worksheets("Menu1").Activate
End
Else
Range("A1").Select
ActiveSheet.ShowDataForm
End If
End Sub
Sub Add_Change_Data_2d()
' This sub opens the form to add/change data - distance warehouses to DCS
Call GetDCs
Call Getwarehouses

Worksheets("Distance To DCs").Activate
If nWarehouses = 0 Or nDCs = 0 Then
MsgBox "There is not enough facilities. There is only " & nWarehouses & " warehouses and " & _
nDCs & " DCs in the system", vbExclamation, "Infeasible"
Worksheets("Menu1").Activate
End
Else
Range("A1").Select
ActiveSheet.ShowDataForm
End If
End Sub
Sub Add_Change_Data_3d()
' This sub opens the form to add/change data - distance DCs to Zones
Call GetDCs
Call GetZones

Worksheets("Distance To Zones").Activate
If nZones = 0 Or nDCs = 0 Then
MsgBox "There is not enough facilities. There is only " & nDCs & " DCs and " & _
nZones & " zones in the system", vbExclamation, "Infeasible"
Worksheets("Menu1").Activate
End
Else
Range("A1").Select
ActiveSheet.ShowDataForm
End If
End Sub

Sub Main_Menu()
'
' Main_Menu Macro
' Macro recorded 5/23/2007 by CU
```

```vba
'
'
Sheets("Menu").Select
End Sub
Sub Menu_1()
'
' Main_Menu Macro
' Macro recorded 5/23/2007 by CU
'

'
Sheets("Menu1").Select
End Sub

Sub Rates()
' This submenu displays the transportation rates from the sheet PARAMETERS
Dim r As Variant, t As Variant, o As Variant
r = Range("railrate")
t = Range("truckrate")
o = Range("oceanrate")
MsgBox "The U.S. rail rate is $" & r & ", the U.S. truck rate is $" & t & " and the ocean rate is $" & _
o & " per ton/mile.", vbExclamation, "Rates"

End Sub
Sub Plants()
'
' Plants Macro
' Macro recorded 5/23/2007 by CU
'

'
Sheets("Plants").Select
Range("A1").Select
End Sub
Sub Parameters()
'
' Parameters Macro
' Macro recorded 5/23/2007 by CU
'

'
Sheets("Parameters").Select
Range("A1").Select
End Sub
Sub Warehouses()
'
' Warehouses Macro
' Macro recorded 5/23/2007 by CU
'

'
Sheets("Warehouses").Select
Range("A1").Select
End Sub
Sub DCs()
'
' DCs Macro
' Macro recorded 5/23/2007 by CU
'

'
Sheets("DCs").Select
Range("A1").Select
End Sub
Sub CustomerZones()
'
' CustomerZones Macro
```

```
' Macro recorded 5/23/2007 by CU
'

'
Sheets("Customer Zones").Select
Range("A1").Select
End Sub
Sub Chart_1()
'
' Chart_1 Macro
' Macro recorded 5/23/2007 by CU
'

'
Sheets("Chart1").Select
End Sub
Sub Chart_2()
'
' Chart_2 Macro
' Macro recorded 5/23/2007 by CU
'

'
Sheets("Chart2").Select
End Sub
Sub Chart_3()
'
' Chart_3 Macro
' Macro recorded 5/23/2007 by CU
'

'
Sheets("Chart3").Select
End Sub
```

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