Anaplan

Optimizer Training – Use Case Example

Transportation Optimization

Transportation Problem

ABC Company has three production plants and transports a product to 4 distribution centers (DCs).

Origin - Production Plants:

| Plant | Three Month Production Capacity (units) |
|-----------|---|
| Cleveland | 5000 |
| Bedford | 6000 |
| York | 2500 |

Destination - Distribution Centers (DCs)

| Distribution Center (DC) | Three Month Demand Forecast (Units) |
|--------------------------|-------------------------------------|
| Boston | 6000 |
| Chicago | 4000 |
| St. louis | 2000 |
| Lexington | 1500 |

Transportation Cost Per Unit

| | Cost | Cost per Unit to ship from Origin to Destination | | | | | | | | | |
|-----------|--------|--|-----------|-----------|--|--|--|--|--|--|--|
| | Boston | Chicago | St. Louis | Lexington | | | | | | | |
| Cleveland | \$3 | \$2 | \$7 | \$6 | | | | | | | |
| Bedford | 7 | 5 | 2 | 3 | | | | | | | |
| York | 2 | 5 | 4 | 5 | | | | | | | |

Questions

- 1. What quantity of product should be scheduled from each plant to each distribution center to achieve the lowest overall shipping cost?
- 2. What is the minimum total shipping cost?
- 3. If ABC Company could add 1000 units of extra capacity at one plant, which would give them the lowest total shipping cost and how much money would they save?
- 4. If all shipping could be purchased at a flat rate of \$3 per unit, should the ABC Company take that offer? Why or why not?
- 5. What is the optimum set of Plant-to-DC Quantity Shipped if the ABC Company were expanded by one plant (capacity 4200 units) and two DCs (demand of 2000 and 2200 units, respectively)? Transportation cost will be \$4 per unit from any plant to the new DCs or from the new plant to existing DCs.

Problem Analysis

The objective is to determine the routes to be used and the quantity to be shipped via each route that will provide the minimum total transportation cost (objective is minimize).

Overall Task:

• Find the set of shipment quantities for each Origin/Destination pair that meets demand while minimizing total shipping cost.

Constraints:

- Total Quantity shipped by **all** Plants to **each** Distribution Center must not exceed the forecast demand quantity of that DC.
- Total Quantity shipped from each Plant must not exceed the Production capacity of that Plant

Variables:

• Quantity Shipped by Plant and by Distribution Center (12 variables, one for each Origin/Destination pair)

Objective Function:

• Total Shipping Cost = Σ (Quantity Shipped * Shipping Cost per Unit) (Sum of all 12 Origin/Destination pairs)

General observations:

The objective function is linear: shipping cost is directly proportional to quantity shipped. The function does not include polynomials (squares, cubes, etc.), inverses (1/x), exponentials (e^x), logarithms, trigonometric functions (sin, cos, tan, ...) or other functions that would cause the cost to have something other than a straight-line relationship with quantity. It is quite common for business-related problems to have linear form. Some example:

Full cost = Fixed Cost + Quantity * Variable Cost per unit

Sales = Quantity * Price

Profit = Sales – Cost of Goods Sold – Overhead Expenses

Ending Inventory = Beginning Inventory – Quantity Shipped + Quantity Received

If the problem cannot be stated in linear terms, then a linear programming algorithm cannot solve it.

- 2. York-Boston, Cleveland-Chicago, and Bedford-St Louis have the lowest shipping cost per unit. The solution should favor those three Plant-DC pairs.
- 3. Bedford-Boston and Cleveland-St Louis are the most expensive shipping routes. The solution should use those only as a last resort.
- 4. Total Supply and Total Demand are equal. In reality, that is rarely the case. In the case of "What if the company had 1000 units of extra capacity?", this relationship changes. When we test using a "shipments must be *less than or equal to* demand", we accommodate conditions where capacity and demand are out of balance.
- 5. Questions 3 through 5 are "What If?" cases. Our model should have the ability for users to enter alternative assumptions and find new cost-optimizing solutions. Question 5 requires us to add a plant and two distribution centers to the model and to input the necessary demand, capacity, and shipping cost values. Note that each scenario *might* impact the others. Extra capacity (from question 3) in different locations may alter the solution to question 4 and 5 and vice versa!

Model Design

For an Optimization model, we typically use four categories of modules:

1) Assumptions

These modules are home to the "known knowns" ... the factors that quantify the problem. How much? How fast? How often?

2) Constraints

These module sets practical boundaries on the problem. In Anaplan, a constraint must be stated as a TRUE or FALSE expression. These are known as Boolean expressions. Examples of constraints in supply chain problems include "Does this amount of stuff ordered fit into a shipping container?" or "Can the factory produce this much?" or "Does the amount shipped equal the amount customers will buy?"

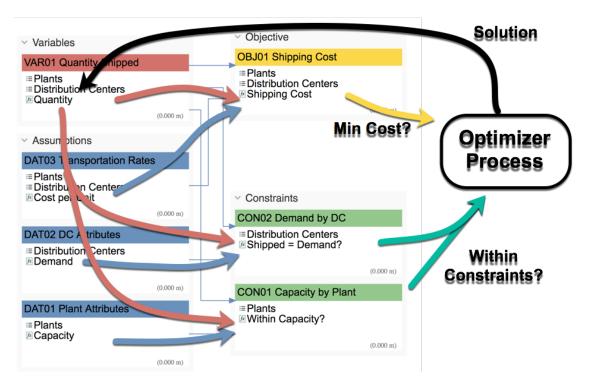
3) Objective

The function to be optimized. Typically, in business cases we want to minimize cost or maximize sales or profit. In network problems, the objective may be to minimize distance traveled or minimize the number of nodes being hopped.

4) Variables

The "known unknowns"; numerical choices we could make to achieve the Objective without violating the Constraints. Variables must be numeric (not dates, text, or other types of data) and those numbers may be either integer values or real numbers.

Here's a schematic of the model you'll build. Models (applications) consist of interconnected modules. Each colored title represents a module. Each colored arrow shows how information passes "downstream" to another module. The Optimizer process finds the set of Variables that satisfy the Objective while remaining within the Constraints. Constraints are TRUE / FALSE Booleans that evaluate whether the Variables and feasible given the Assumptions.



Step by Step Instructions

We assume that you are familiar with model building; we will start from a-new model for this exercise.

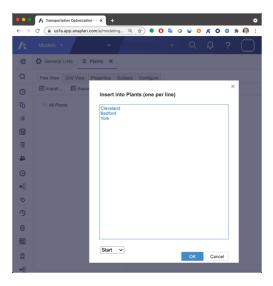
Let's start by creating 2 lists: Plants and Distribution Centers.

For Plants, add a Top Level: All Plants.

And for Distribution Centers add a Top Level named All DCs.

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| > | ✿ General Lists := Plants × | | | | | | |
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| ٩ | | Top Level | Parent Hierarchy | Selective Access | Production Data | Managed By | Has Workflow |
| 0 | Plants | All Plants | | | | | |
| Co | Distribution Centers | All DCs | | | | | |
| | General Lists | | | | | | |
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We need to add three plants: Cleveland, Bedford, and York.



And 4 destinations to the Distribution Centers list

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| K | Models • • Q Q ? |
| > | General Lists := Distribution Centers × |
| Q | Tree View Grid View Properties Subsets Configure |
| ٩ | 🔛 Import 🔃 Export 🕒 Insert 🖨 Delete 🗘 Move 📢 Refresh 🔍 🗸 |
| CO | All DCs Boston |
| := | Chicago St. Louis |
| | - Lexington |

We are going to organize our modules and dashboard into 5 Functional Areas that were discussed in the Model Design section.

- Assumptions
- Variables
- Constraints
- Objective
- And a reporting one: User Dashboard

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| - | Category |
| CO | User Dashboard |
| := | Assumptions Variables |
| := | Constraints |
| | Objective |
| ≣ | |

Create and configure 3 assumptions modules.

1. Name: DAT01 Plant Attributes

Dimension: Plants (List)

Functional Area: Assumptions

Line Items: 1

- Name: Capacity
- Format: Number (default)
- Summary: Sum (default)
- Formula: <none ... this is an input>

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|) | 🗘 Modules 🗐 🛙 | AT01 Plant Attributes | × | | | | | | | | | | | |
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| ٩ | Line Item Formula | | | | | | | | | | | | | |
| G | Separate Capacity | | | | | | | | | | | | | |
| = | | | Format | | Formula | I | | Summ | ary | | | | A | pplies T |
| | DAT01 Plant Attributes | | | | | | | | | | Plants | | | |
| | Capacity | | Number | | | | Sum | | | | • | | | |
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2. Name: DAT02 DC Attributes

Dimension: Distribution Centers (List)

Functional Area: Assumptions

Line Items: 1

- Name: Demand
- Format: Number (default)
- Summary: Sum (default)
- Formula: <none ... this is an input>

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| >0 | Modules | DAT01 Plant Attributes | | 02 DC Attributes | × | | | | | | | | | | | | |
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| ٩ | Line Item For | nula | | | | | | | | | | | | | | | |
| CD | ★ Demand | | | | | | | | | | | | | | | | |
| = | | | Format | | | Formula | | | | Su | ummar | у | | | | | Applies To |
| | DAT02 DC Attri | | | | | | | | h | | | | | | oution Cer | iters | |
| | Demand | | Number | | | | | | Sum | | | | | | | | |
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3. Name: DAT03 Transportation Rates

Dimensions: Plants, Distribution Centers (Lists)

Functional Area: Assumptions

Line Items: 1

- Name: Cost per Unit
- Format: Number (default)
- Summary: Average
- Formula: <none ... this is an input>

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| := | | | Format | Formula | Summary | Applies To |
| | DAT03 Transport | ation Rates | | | | Plants, Distribution Centers |
| | Cost per Unit | | Number | | Average | • |
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In this module, it doesn't make sense to sum the cost per unit values to the parents All Plants and All DCs. Change the Summary method to Average.

Next create a module to hold the variable inputs.

| Name: | : VAR01 Quantity Shipped |
|----------|---|
| Dimen | sion: Plants, Distribution Centers (Lists) |
| Function | onal Area: Variables |
| Line Ite | ems: 1 |
| • | Name: Quantity |
| • | Format: Number (default) |
| • | Summary: Sum (default) |
| • | Formula: <none be="" by="" generated="" td="" the<="" values="" will=""></none> |
| | optimizer engine> |

Now create two more modules for calculating the constraints.

| Name: CON01 Capacity by Plant | Name: CON02 Demand by DC | | | | | |
|--------------------------------------|--|--|--|--|--|--|
| Dimension: Plants (List) | Dimension: Distribution Centers (List) | | | | | |
| Functional Area: Constraints | Functional Area: Constraints | | | | | |
| Line Items: 1 | Line Items: 1 | | | | | |
| Name: Within Capacity? | • Name: Shipments = Demand? | | | | | |
| Format: Boolean | Format: Boolean | | | | | |
| Summary: All | Summary: All | | | | | |
| Formula: | Formula: | | | | | |
| 'VAR01 Quantity Shipped'.Quantity <= | 'VAR01 Quantity Shipped'.Quantity = | | | | | |
| 'DAT01 Plant Attributes'.Capacity | 'DAT02 DC Attributes'.Demand | | | | | |
| | | | | | | |

Note that these two formulas are Boolean expressions that evaluate to either TRUE or FALSE depending on whether the necessary conditions are met.

Also note that these roll up to the top level of the list using "All". If all of the plants or DCs pass the test (TRUE) then the top level member will be true. If any of the plants or DCs fail the test, the top level member will be false.

<u>The ALL summary setting is required by the optimizer.</u> Without the summary setting of All, the optimizer job will fail with an error message explaining the problem.

And now create your last module for calculating the objective function.

| Name: OBJ01 Shipping Cost | | | | | | |
|---------------------------|-----------------------------------|--|--|--|--|--|
| Dimension: Plants, [| Distribution Centers (Lists) | | | | | |
| Functional Area: Ob | jective | | | | | |
| Line Items: 1 | | | | | | |
| Name: Ship | oping Cost | | | | | |
| • Format: | Number (default) | | | | | |
| • Summary: S | um (default) | | | | | |
| • Formula: | | | | | | |
| 'DAT03 Trar | sportation Rates'.Cost per Unit * | | | | | |
| | ntity Shipped'.Quantity | | | | | |
| | , | | | | | |

Let's move on to Dashboard creation

Add a new dashboard "Transportation Optimization" and publish all module on this dashboard.

Next, create the Optimizer action.

On the Model Settings tab, select Actions from the menu list, then choose New Action, Optimizer on the main panel*.

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| 8 | Actions | DAT01 Plant Attributes X | DAT02 DC Attributes × | DAT03 Transportation Rates | < | | | | | | |
| 2 | Actions Imp | orts Import Data Sources | 9 | | | | | | | | |
| 3 | View 👻 📘 | New Action 👻 💿 🥌 | Delete | Manage Import Data Sources | Export | Refresh | Q.+ | | | | |
| 'n | | Process | | Action | | Sta | art Date and | Time (UTC | | | |
| 0 | Processes Find Solut | Delete from List using Selection | | | | | | | | | |
| = | Imports | Order List | | | | | | | | | |
| | Exports Other Action | Open Dashboard | | | | | | | | | |
| - | Find Optin | Create | Optimizer | | | | | | | | |
| | | Delete Branch | | | | | | | | | |
| Э | | Assign | | | | | | | | | |
| | | Update Current Period | | | | | | | | | |
| ß | | Copy Branch | 3 | | | | | | | | |
| 0 | | Assign Only | 3 | | | | | | | | |
| Э | | Optimizer | | | | | | | | | |
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Fill out the form to configure the Optimizer action, click OK when complete.

*Note: if you do not see the Optimizer action, contact your Anaplan account team.

| Button text: | Find Optimum |
|---------------|--|
| Time Out: | 300 seconds (default) |
| Problem: | Linear Programming |
| Objective: | Minimize |
| Line Item: | OBJ01 Shipping Cost.Shipping Cost |
| Variable 1: | VAR01 Quantity Shipped.Quantity |
| | (Integer between 0 and 50000) |
| Constaints 1: | CON01 Capacity by Plant.Within Capacity? |

Constraints 2: CON02 Demand by DC.Shipped = Demand?

| > | Actions | DAT01 Plant Attributes 🗙 🛗 DAT02 DC Attributes 🗴 🛗 DAT03 Transportation Rates 🗙 | |
|-------------|----------------------------|---|-------|
| O, | Actions Imports | Import Data Sources | |
| ٩ | | Action 👻 💮 Run. 🥒 Edit 🔵 Delete 🛊 Reorder Manage Import Data Sources 📴 Export 🔇 Ref | fresh |
| Co | Q + | Find Optimum | |
| := | Processes Find Solution | Time Out - 300 + seconds | |
| | Imports | | |
| 2 | Exports Other Actions | Problem | |
| <u></u> | Find Optimum | * Problem Linear Programming | |
| | | Objective | |
| •0 | | * Objective Minimize Maximize | |
| \bigcirc | | * Line Item OBJ01 Shipping Cost. Shipping Cost 👻 | |
| 3 | | Variable(s) | |
| | | * Variable 1 VAR01 Quantity Shipped Quantity 🗸 🗢 👁 | |
| 8D | | Integer | |
| Д | | Constraint(s) | |
| ■ 00 | | Constraints 1 CON02 Demand by DC.Shipped = Dr 	 ● | |
| | | Constraints 2 CON01 Capacity by Plant.Within Cap - | |
| | | | |
| | | OK Cancel | |
| 0 | | | |
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Create a Process that contains the Find Optimum action and publish that Process (as a button) onto your dashboard. To do this, click on New Action, Process. Enter the name "Find Solution" in the dialog box and click OK.

You'll now see "Find Solution" listed under Processes; Select it and click Edit. Add the Find Optimum action to the process and click OK.

| >= | Actions | DAT01 Plant Attributes 🗙 | DAT02 DC | C Attributes | × (| DAT03 Transportation Rates | × | | |
|----------|------------|--|---------------------|--------------|--------|----------------------------|---|--------|---|
| O, | Actions In | nports Import Data Sources | | | | | | | |
| Ŀ | Find | Solution | | | | | | | × |
| CD | Ava | ailable Actions | | | Select | ted Actions | | | |
| := | Pr 📃 | Other Actions | | | Find C | Optimum | R | emove | |
| | lm Ex | Find Optimum | | | | | | | |
| | Ot | | | | | | | | |
| * | Di: | splay action confirmation and full res | sult details to end | d-users when | runnin | ig this process | | | |
| • | | | | | | ОК | | Cancel | |
| •~~ © | _ | | _ | | | | | | |

The final steps of polishing the dashboard for end user presentation is left as an exercise for the student. Here is a screenshot of a dashboard with a title and sub-headings and arranged in a logical order. Note that the modules may have been pivoted to place Plants or DCs in rows / columns and Line Items as page dimensions. And don't forget to publish your "Find Solution" process on your dashboard.

Have fun arranging your own.

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| > | Cashboards | ansportation Optimization $$ X | | | | | | | | | | | |
| Q | _ | | | | | | | | | | | | |
| ٩ | Transportati | on Optimization | | | | | | | | | | | |
| CO | 1. Input Demand by | → DAT02 DC Attributes Demand ▼ | | | | | | | | | | | |
| := | DC, Capacity by Plant, and Transportaion | | | | | | | | | | | | |
| | Rates by Plant-DC | ⊺ Boston ├ Chicago | 6,000 4,000 | | | | | | | | | | |
| - | | St. Louis | 2,000 | | | | | | | | | | |
| E | | - Lexington - Dallas | 1,500 | | | | | | | | | | |
| * | | Oakland | 2,200 | | | | | | | | | | |
| 0 | | All DCs | 17,700 | | | | | | | | | | |
| \odot | | DAT01 Plant Attributes Capacity | | | | | | | | | | | |
| €° | | | | | | | | | | | | | |
| 0 | | Cleveland | 5,000 | | | | | | | | | | |
| | | - Bedford - York | 6,000 2,500 | | | | | | | | | | |
| 3 | | Phoenix | 4,200 | | | | | | | | | | |
| | | - All Plants | 17,700 | | | | | | | | | | |
| 即 | | DAT03 Transportation Rates Cost per | Unit 🔻 | | | | | | | | | | |
| | | | | | St. Louis | Lexington | Dallas | Oaklan | d | All DCs | | | |
| | | Cleveland Bedford | 3 | 7 5 | 2 | | | 4 4 | 4 | 4.33 | _ | | |
| - 60 | | York | 7 | 2 | 4 | 4 4 | | 4 | 4 | 4.16 | 7 | | |
| | | Phoenix | 4 | 4.5 | 3.75 | | - | 4 4 | 4 | 4.16 | 4 | | |
| | 2. Calculate optimum solution | Find Solution • VAR01 Quantity Shipped Quantity • | | | | | | | | | _ | | |
| | | Roston | Cleveland Bedfo | 6,000 | York 0 | Phoenix | All Plants 6,000 | | | | | | |
| | | ☐ Boston - Chicago | 0 | 0 | 2,500 | 1,500 | 4,000 | | | | | | |
| | | St. Louis | 2,000 | 0 | 0 | 0 | 2,000 | | | | | | |
| | | - Lexington - Dallas | 2,000 | 0 | 0 | 1,500 0 | 1,500 2,000 | | | | | | |
| | | Oakland | 1,000 | 0 | 0 | 1,200 | 2,200 | | | | | | |
| 6 | 3. Have constraints been met? | ► CON02 Demand by DC Shipped = Demand? ▼ Boston Chicago St. Louis Louis targe | 5,000 | 6,000 | 2,500 | 4,200 | 17,700 | | | | | | |
| ţţţ | | Lexington Dallas | | | | | | | | | | | |

If you are leveraging the New UX, here is an example of our Optimizer Board

| Apps ~ | rtation Optimization - Hendersc | / Transpor | tatic 🗸 | 💬 Feedback | ơ Ô | ? мн |
|----------------------|---------------------------------|------------|------------------|--------------|-------------------|---------|
| Transportation | n Optimization 🖕 < | | | Shipping Cos | st ∨ Reset | 0 |
| Transportation Op | timization: Assumptions | | | | | |
| | Transpo | rtation C | Optimizati | on | | |
| | | | | | | |
| Enter Capacity by | Plant | E | nter Demand by D | ist Center | | |
| Cleveland | 5,000 | | Boston | | 6,000 | |
| Bedford | 6,000 | | Chicago | | 4,000 | |
| York | 2,500 | | St. Louis | | 2,000 | |
| All Plants | 13,500 | | Lexington | | 1,500 | |
| | 10,000 | All | DCs | | 13,500 | |
| | | | | | | |
| Enter Transportation | on Rates | | | Ru | n Optimizer | |
| | | | | | Find Soluti | lon |
| | Boston | 3 | | | | |
| | Chicago | 7 | | | | |
| Cleveland | St. Louis | 2 | | | | |
| | Lexington | 6 | | | | |
| | All DCs | 4.5 | | | | |
| | Boston | 2 | | | | |
| | Chicago | 5 | | | | |
| Bedford | St. Louis | 5 | | | | |
| boarona | | | 1 | | | |
| | Lexington | 5 | | | | |
| | All DCs | 4.25 | | | | |
| | Boston | 7 | | | | |
| | Chicago | 2 | | | | |
| York | St. Louis | 4 | | | | |
| | Lexington | 4 | | | | |
| | All DCs | 4.25 | | | | |
| | | | | | | |
| Results: Optimize | d Quantity Shipped | | | | | |
| | Boston | Chicago | St. Louis | Lexington | n / | All DCs |
| Cleveland | | | | | | |
| Bedford | | | | | | |
| York | | | | | | |
| All Plants | | | | | | |
| | | | | | | |
| Results: Total Ship | aping Cost | | | | | |
| | Boston | Chicago | St. Louis | L ovin -t | | All DCs |
| | Boston | Chicago | St. LOUIS | Lexington | , , | ui DUS |
| Cleveland | | | | | | |
| Bedford | | | | | | |
| York | | | | | | |
| All Plants | | | | | | |
| | | | | | | |

One step further

If you want to continue practicing, here are a couple of questions you can answer autonomously.

1. What is the optimum set of Quantity Shipped amounts from each plant to each DC?

Quantity Shipped

| | Boston | Chicago | St. Louis | Lexington |
|-----------|--------|---------|-----------|-----------|
| Cleveland | | | | |
| Bedford | | | | |
| York | | | | |

- 2. What is the minimum total Shipping Cost (All Plants, All DCs) in that optimized case?
- 3. Engineering at the company's R&D center just called. They have a pilot manufacturing line they no longer need. It has a capacity of 1,000 units per 3 months. To make room at the R&D center, it needs to go. You realize that even without any increase in demand, this flexibility can reduce overall shipping costs.

At which plant should you install this extra capacity to reduce shipping costs the most? How much will total Shipping Cost decrease with that extra capacity?

4. A transportation logistics supplier has come to the company with a proposal for flat-rate shipping charges: \$3 per unit between any Plant and any DC.

Should you accept this deal? Why or why not? Does this decision change your choice in question 3 on where to put the extra capacity?

5. The executive team is considering the acquisition of a company that has a manufacturing plant in Phoenix (capacity 4200 units) and distribution centers in Dallas (demand 2,000 units) and Oakland (demand 2,200 units). Remember, you still have the option of placing 1000 units of extra capacity somewhere...

| | Boston | Chicago | St. Louis | Lexington | Dallas | Oakland |
|-----------|--------|---------|-----------|-----------|--------|---------|
| Cleveland | 3 | 7 | 2 | 6 | 4 | 4 |
| Bedford | 2 | 5 | 5 | 5 | 4 | 4 |
| York | 7 | 2 | 4 | 4 | 4 | 4 |
| Phoenix | 4 | 4 | 4 | 4 | 4 | 4 |

Transportation cost per unit:

Assuming the merger goes through, at which plant should the 1000 units of extra capacity be installed to minimize total Shipping Cost?

What is the optimum set of Quantity Shipped by origin/destination of the combined companies?

| | Boston | Chicago | St. Louis | Lexington | Dallas | Oakland |
|-----------|--------|---------|-----------|-----------|--------|---------|
| Cleveland | | | | | | |
| Bedford | | | | | | |
| York | | | | | | |
| Phoenix | | | | | | |