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 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:

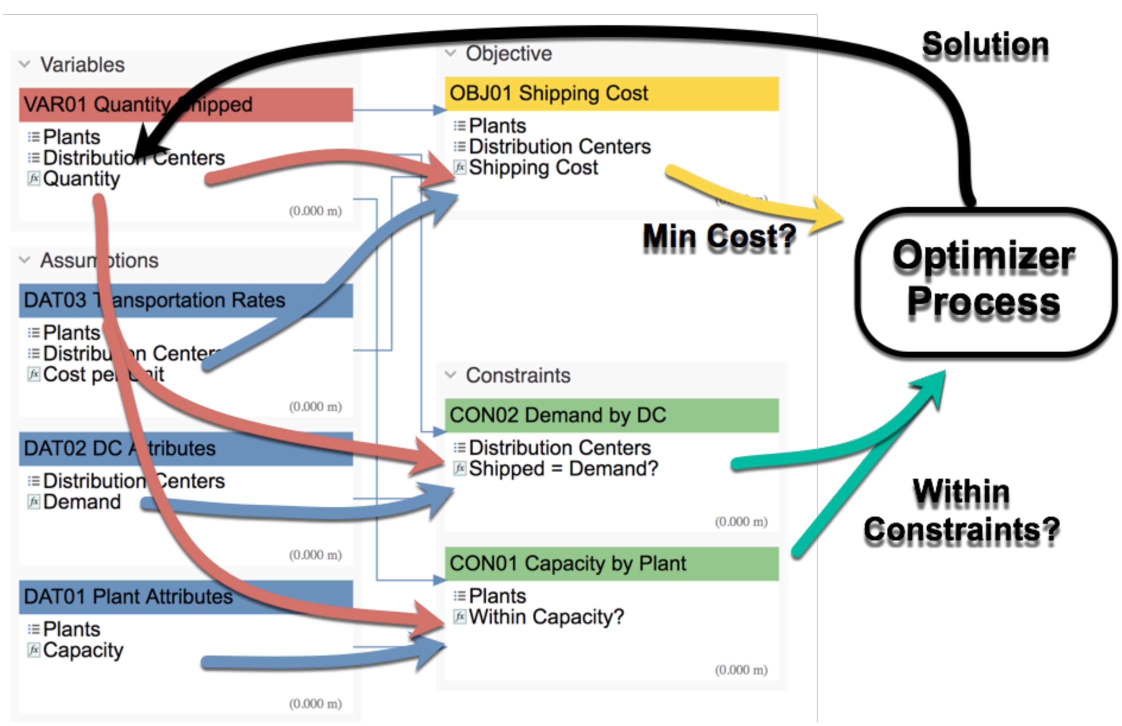
1. The objective function is linear: shipping cost is directly proportional to quantity shipped. The function does not include polynomials (squares, cubes, etc.), inverses (1/x), exponentials (e^x), logarithms, trigonometric functions (sin, cos, tan, …) or other functions that would cause the cost to 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.



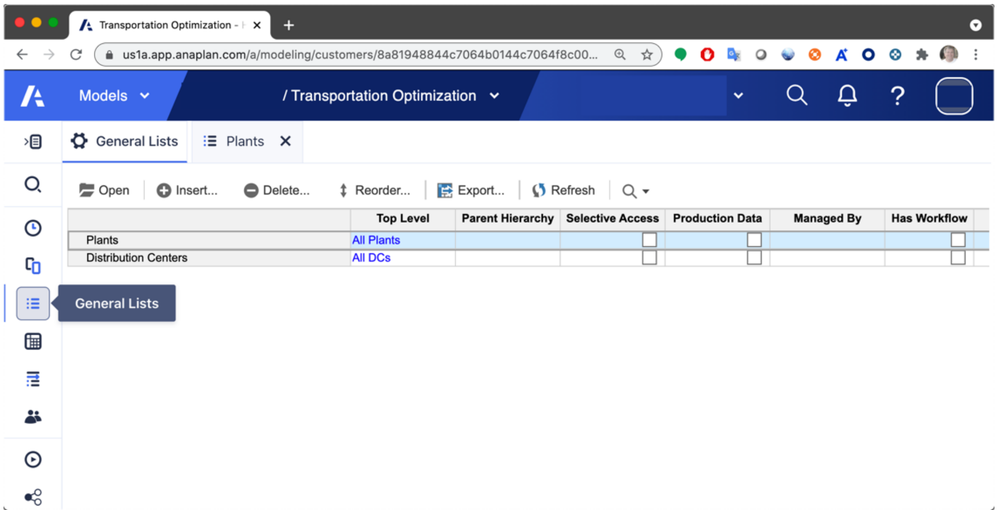
Step by Step Instructions

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

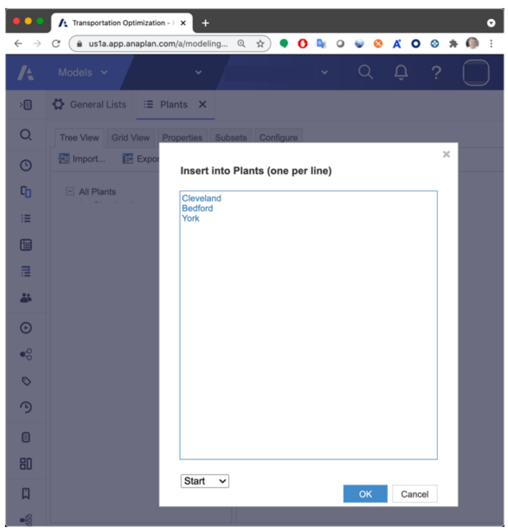
Let's start by creating 2 lists: Plants and Distribution Centers.

For Plants, add a Top Level: All Plants.

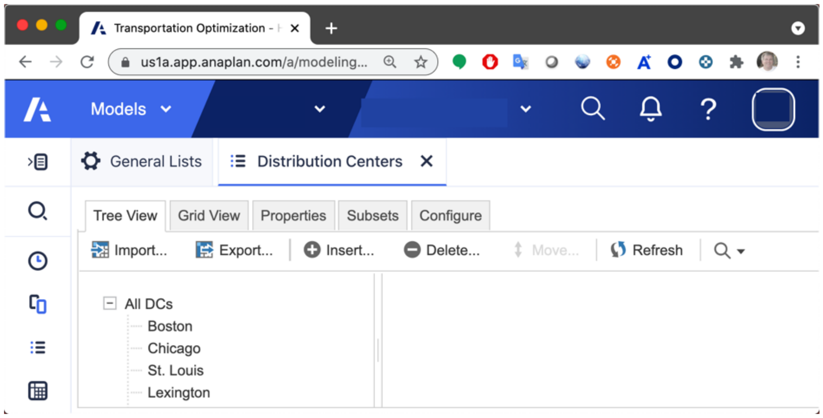
And for Distribution Centers add a Top Level named All DCs.



We need to add three plants: Cleveland, Bedford, and York.

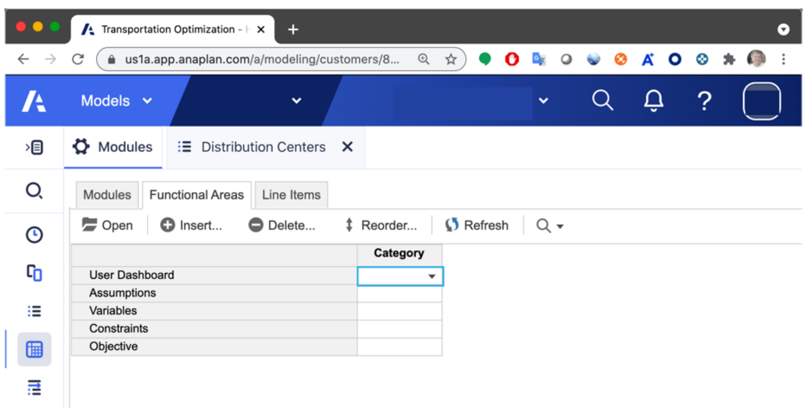


And 4 destinations to the Distribution Centers list



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



Create and configure 3 assumptions modules.

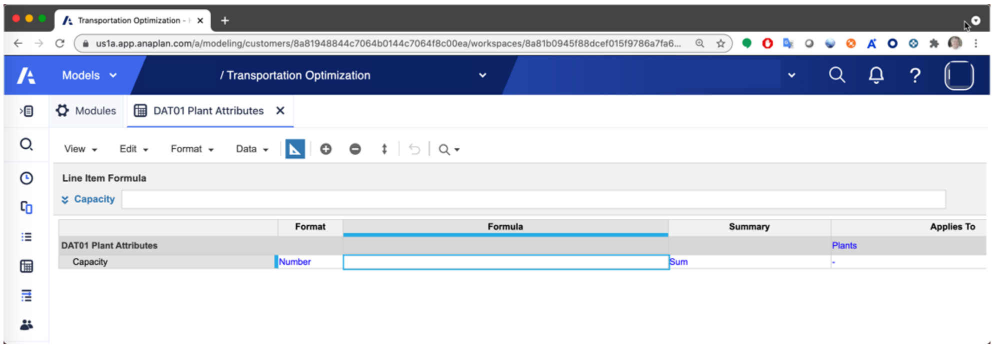
1. Name: DAT01 Plant Attributes

Dimension: Plants (List)

Functional Area: Assumptions

Line Items: 1

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



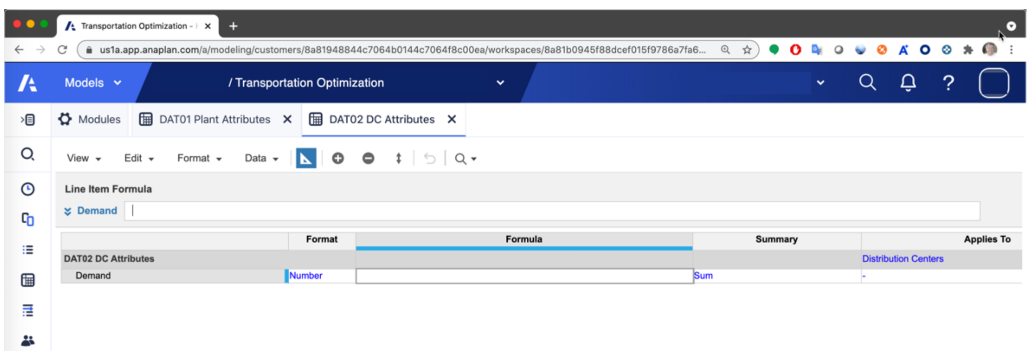
2. Name: DAT02 DC Attributes

Dimension: Distribution Centers (List)

Functional Area: Assumptions

Line Items: 1

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



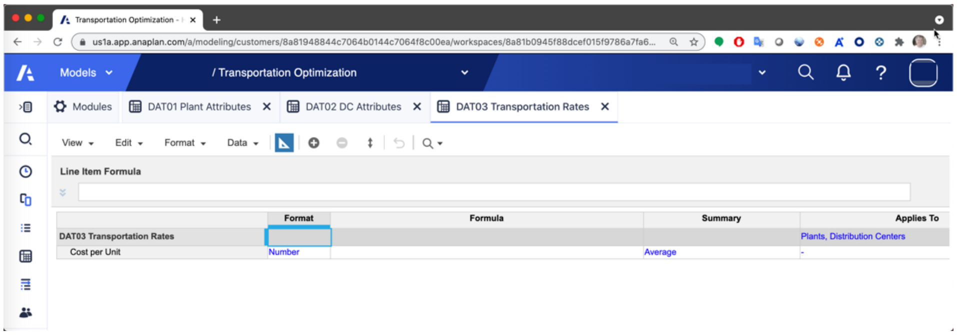
3. Name: DAT03 Transportation Rates

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>



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 Dimension: Plants, Distribution Centers (Lists) Functional Area: Variables Line Items: 1 • Name: Quantity • Format: Number (default) • Summary: Sum (default) • Formula: <none … values will be generated by the optimizer engine>

Now create two more modules for calculating the constraints.

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

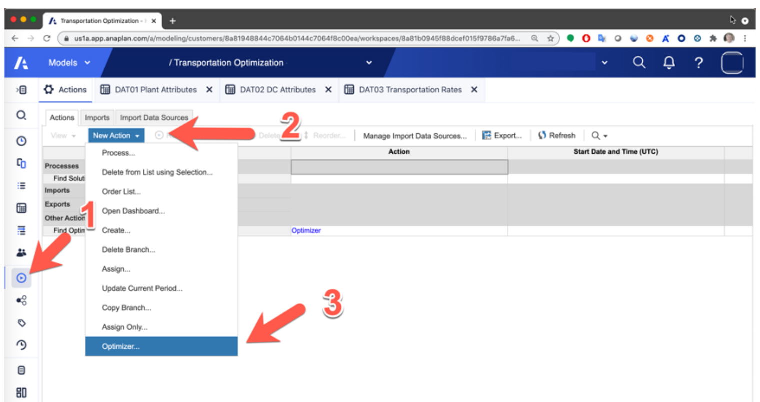
Name: OBJ01 Shipping Cost Dimension: Plants, Distribution Centers (Lists) Functional Area: Objective Line Items: 1 • Name: Shipping Cost • Format: Number (default) • Summary: Sum (default) • Formula: 'DAT03 Transportation Rates'.Cost per Unit * 'VAR01 Quantity Shipped'.Quantity

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*.



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

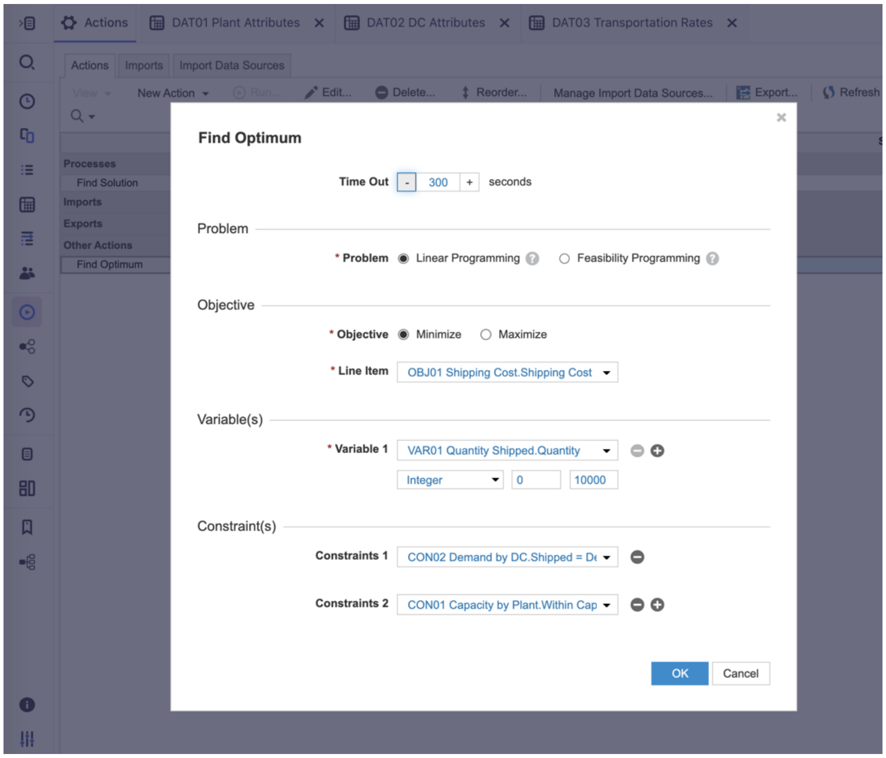
Line Item: OBJ01 Shipping Cost.Shipping Cost

Variable 1: VAR01 Quantity Shipped.Quantity

(Integer between 0 and 50000)

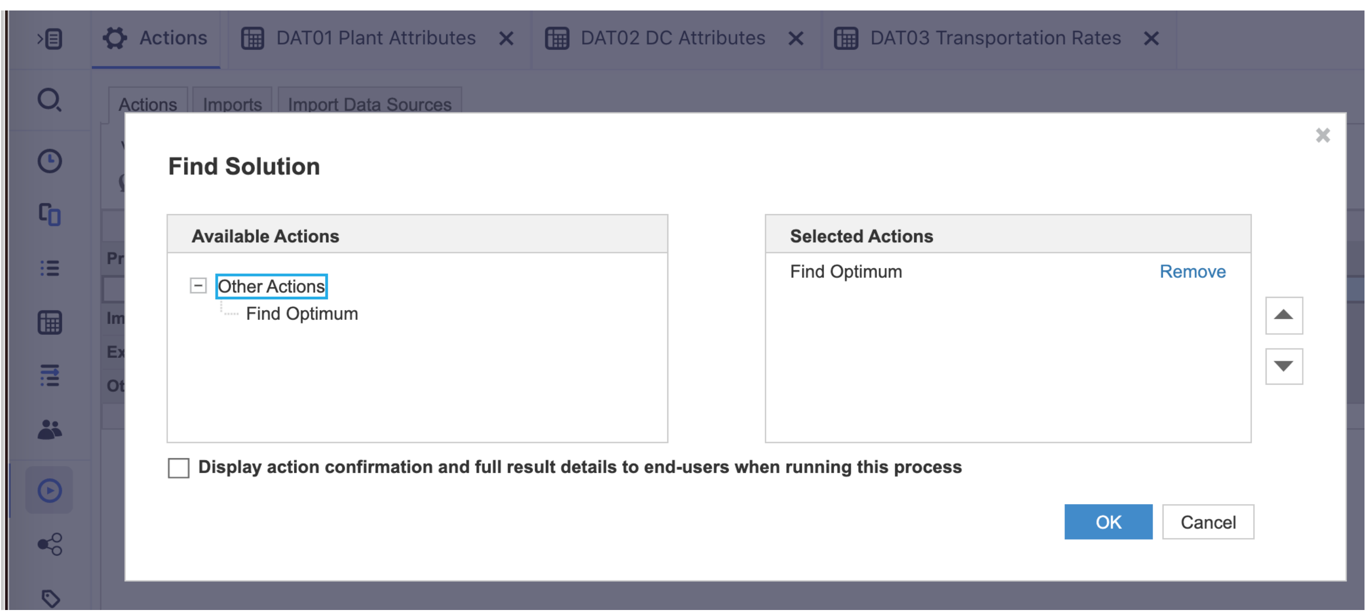
Constaints 1: CON01 Capacity by Plant.Within Capacity?

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



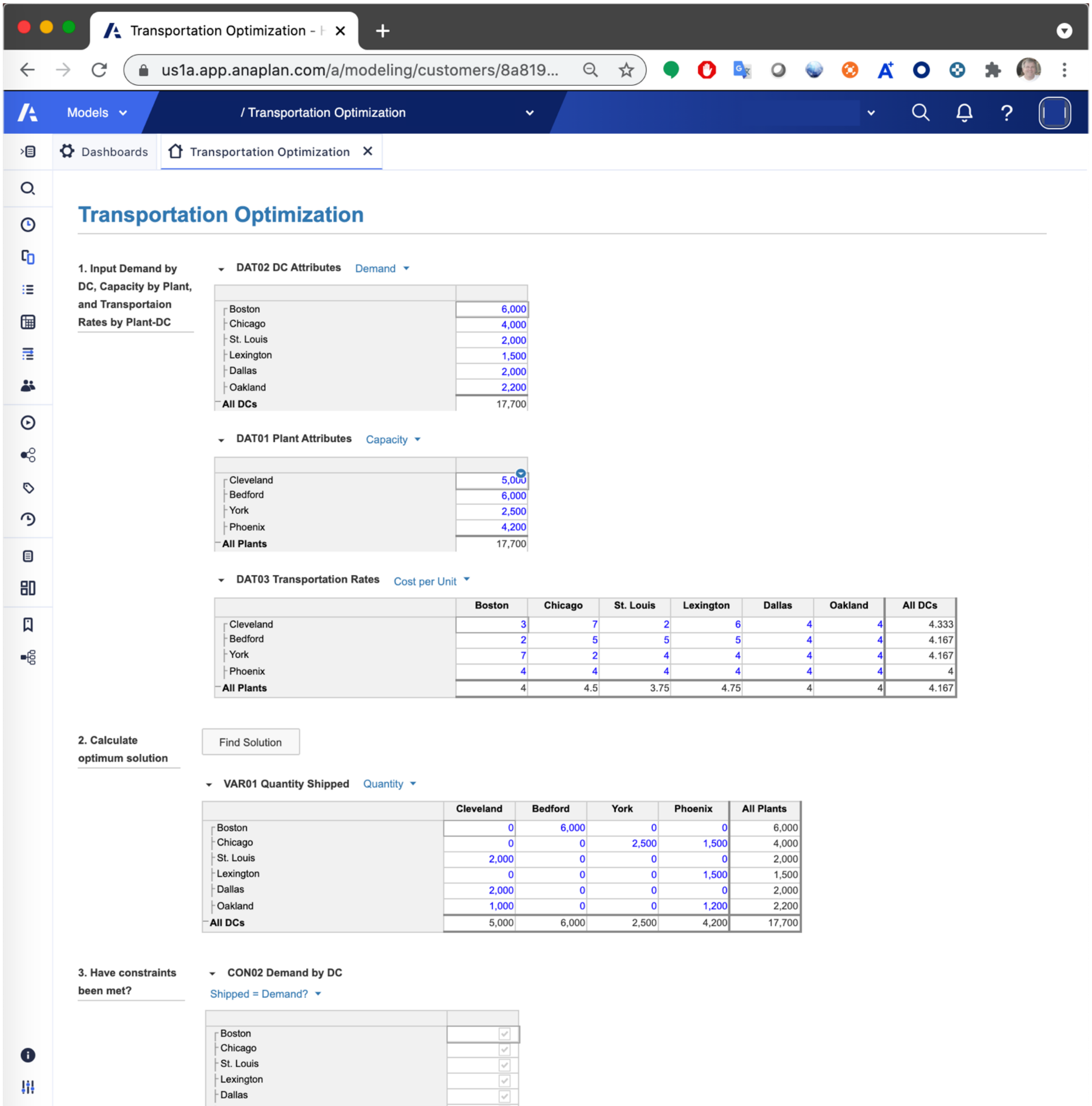
Create a Process that contains the Find Optimum action and publish that Process (as a button) onto your dashboard. To do this, click on New Action, Process. Enter the name "Find Solution" in the dialog box and click OK.

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.

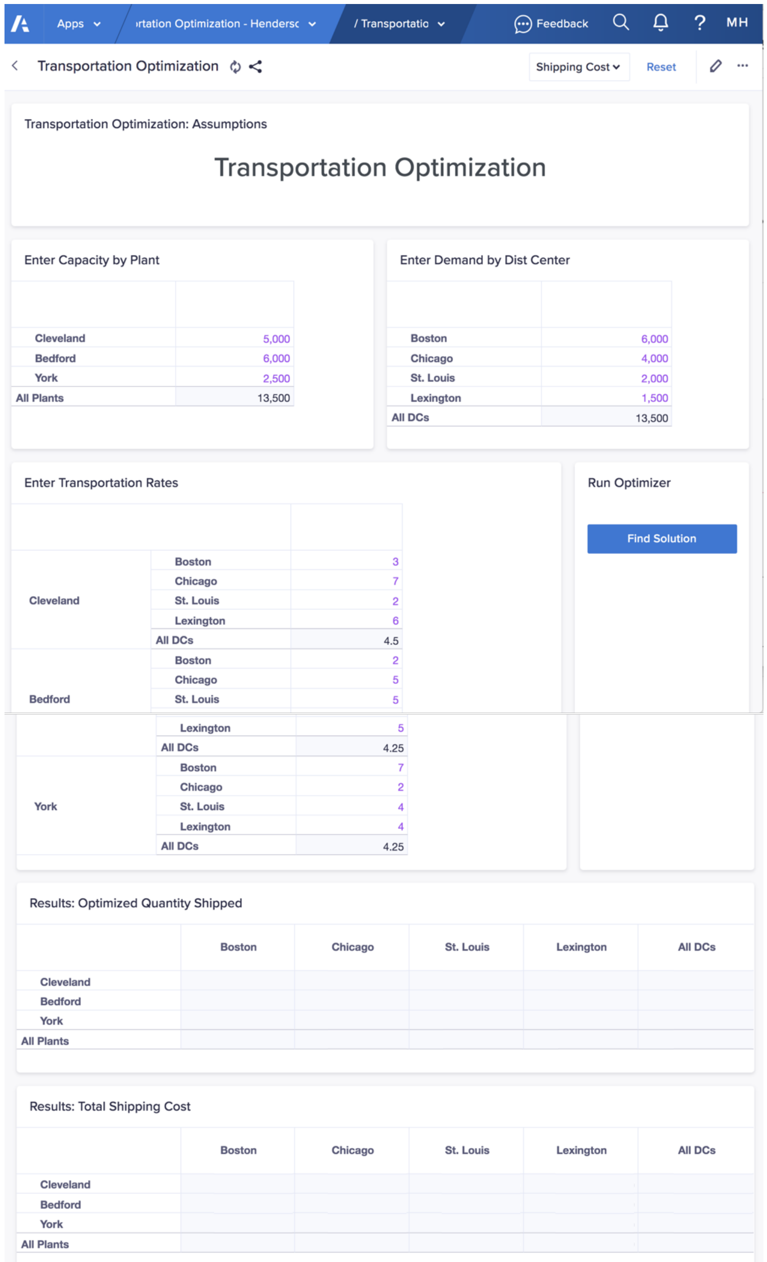


The final steps of polishing the dashboard for end user presentation is left as an exercise for the student. Here is a screenshot of a dashboard with a title and sub-headings and arranged in a logical order. Note that the modules may have been pivoted to place Plants or DCs in rows / columns and Line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

Have fun arranging your own.



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



Enter Capacity by Plant

Cleveland	5,000
Bedford	6,000
York	2,500
All Plants	13,500

Enter Demand by Dist Center

Boston	6,000
Chicago	4,000
St. Louis	2,000
Lexington	1,500
All DCs	13,500

Enter Transportation Rates

Cleveland	Boston	3
	Chicago	7
	St. Louis	2
	Lexington	6
	All DCs	4.5
Bedford	Boston	2
	Chicago	5
	St. Louis	5
	Lexington	5
	All DCs	4.25
York	Boston	7
	Chicago	2
	St. Louis	4
	Lexington	4
	All DCs	4.25

Results: Optimized Quantity Shipped

	Boston	Chicago	St. Louis	Lexington	All DCs
Cleveland					
Bedford					
York					
All Plants					

Results: Total Shipping Cost

	Boston	Chicago	St. Louis	Lexington	All DCs
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…

   Transportation cost per unit:

	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

   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						