Question A (related to network design, redundancy, risk)

XYZ Inc., a Canadian beverage company, is considering breaking into the US market in five major cities: Albany, Atlanta, Austin, Boston, and Chicago.

It has scouted out a potential location in each city to serve as a production plant. Below are the fixed operating costs and capacities of each plant. For convenience in unit conversion, the analysts have provided all numbers in weeks.

City	Fixed Operating Costs (weekly)	Production Capacity (tons, weekly)
Albany	$20,000	700
Atlanta	$20,000	200
Austin	$10,000	100
Boston	$30,000	200
Chicago	$20,000	100

However, XYZ Inc. does not have to open facilities in all five cities to serve customers in all five cities: product can be shipped from the facility in one city to the customers in another city, for a transportation cost. It may be beneficial to avoid paying the fixed operational overhead from renting and operating a facility in all five cities.

To estimate transportation costs, the analysts used a mileage chart between the cities:

DISTANCE (miles)	Albany	Atlanta	Austin	Boston
Atlanta	957			
Austin	1798	907		
Boston	165	1037	1907	
Chicago	795	678	1116	960

The rate of shipping a ton of goods for one mile is 15 cents, using a train. Therefore, the cost to ship a ton of product from Chicago to Boston is $0.15*960, or $144. Similar shipping costs (in $/ton) can be calculated for each pair of cities.

Unfortunately, the train system does not stop by Albany. Any direct shipment involving Albany must be multiplied by the higher rate of 30 cents per ton-mile, since it is delivered using a truck. If this option is too expensive, the delivery system is allowed to use a nearby city as a drop-off. For example, to deliver from Chicago to Albany, it is possible to stop through Boston (where the product is transferred from train to truck) to reduce costs, even if there is no facility open in Boston.

To estimate weekly demand, the analysts assume that an average American in one of these cities consumes 0.6 cans (which are 355mL) per week. Therefore, the weekly consumption is 0.213L/person. For simplicity, the company assumes that 1000 liters of product equals 1 ton, so the weekly consumption is 0.000213 tons per person. The populations of the cities are given below:

City	Population (2013 est.)
Albany	98,000
Atlanta	448,000
Austin	885,000
Boston	646,000
Chicago	2,719,000

The company is not obligated to satisfy the demand in every city. Instead, it tries to maximize its total "revenue minus cost". The demand numbers merely provide an upper bound (i.e. a constraint in the optimization model) for the maximum number of units that can be confidently sold in each city, per week.

Cans are sold at an average wholesale price of 30 cents a liter, while it costs 10 cents to produce a liter. Therefore, the profit per liter procured is 20 cents. Using the same conversion from volume to mass, the profit per ton procured is $200.

XYZ Inc. is trying to maximize the total profit earned from demand satisfied, minus the fixed weekly operating costs from open facilities, and minus the transportation costs from weekly shipments. XYZ needs to decide how many and which facilities to open, how much product to produce at each location, and how to ship products across cities to serve demand.

1. Using Excel Solver, formulate and solve the optimization problem, with no constraint on the number of facilities opened, and no consideration for risk/redundancy. What is the optimal network design and weekly PNL? Please provide the numbers output by your spreadsheet.
2. Suppose the CEO of XYZ Inc. wanted to impose a constraint on the number of facilities open. That is, for each value of k=1,2,3,4,5, re-solve the optimization problem with the additional constraint that exactly k facilities are open. Compare the optimal PNL's for different values of k in a chart.
3. What do you notice about the shape of the curve? How does it compare with the rule of "Total supply chain cost is always flat around the optimal strategy" (from Lecture 1)? Taking the benefits of redundancy into consideration, what value of k would you recommend? (There is no clear right answer for this part, but please provide reasoning.)
4. Suppose we eliminated the option to send a truck directly to/from Albany for cities other than Boston. That is, to connect any other city to Albany, we would first use a train to Boston, and then send a truck from Boston. Does this additional constraint reduce any of the optimal PNL's you computed?

The CEO ends up deciding to open up all five facilities, being highly concerned about risk. For the remaining questions, treat the optimal solution with k=5 as the baseline PNL.

5. Consider the five scenarios where the facility in a single city breaks down (the fixed cost was already paid, and cannot be recouped). For each one, compute the loss from the baseline PNL.
6. The analysts are not sure how to compare the Time to Recovery (TTR) for different cities, so they assume them to all be the same. In this case, which facility's breakdown poses the greatest risk to XYZ Inc.?

Question B (related to flexibility, strategic inventory vs. supply risk)

Abc is a manufacturer company in beverage industry. It owns four beverage plants at four different locations. Currently, each plant produces a *unique* product family and is running at full capacity. The production capacity of each plant matches the demand rate (see Table 1 and 2). For each beverage product family, Abc estimates that it holds about two million units of finished goods inventory in its pipeline.

After realizing plant disruptions could result loss of market shares, in 2012, Abc has started an initiative to assess its supply chain resiliency using the Time-to-Survive (TTS) metric. TTS is defined as the time duration in which customer demand of all products is satisfied at 100% no matter which single plant is disrupted (and thus the production of that plant is halted).

Beverage Product Family	Demand/week (units)	Inventory (units)
A	4,000,000	2,000,000
B	4,000,000	2,000,000
C	4,000,000	2,000,000
D	4,000,000	2,000,000

Table 1. Products Demand and Inventory

Plant	Capacity/week (units)	No Flexibility	Complete Flexibility	Long chain
Atlanta	4,000,000	A	A, B, C, D	A, B
Bloomington	4,000,000	B	A, B, C, D	B, C
Columbia	4,000,000	C	A, B, C, D	C, D
Dallas	4,000,000	D	A, B, C, D	D, A

Table 2. Plants Production Capacity

1) Suppose Abc has no flexibility to shift its production among its plants (see column 3 of Table 2). What is the TTS of Abc's supply chain? Note that if demand is not satisfied by production, it can be satisfied by inventory.
2) Suppose Abc has configured its plants to have complete flexibility[i] (see column 4 of Table 2). What is the TTS of Abc's supply chain? In particular, suppose Abc uses the following contingency plan: if one of the plants is disrupted, each of the remaining plants divides its capacity equally among four products, so the production rate for each product is 3,000,000 units per week. (*<u>Optional, do not need to hand in</u>*: Show that this contingency plan achieves the maximum TTS. *Hint*: Consider the total demand and total capacity of Abc when one plant is disrupted.)
3) Suppose Abc has added flexibility in its plants to form a long chain flexibility structure (see column 5 of Table 2). Find a contingency plan for Abc so that no matter which plant is disrupted, the production rate for every product remains at 3,000,000 units per week. What does this imply in terms of the TTS of the long chain?
4) We didn't specify the fixed cost of adding flexibility to Abc's plants, but in general, more flexibility is more costly. Compare the TTS in question 2) and 3), what does the result imply?

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[i] Suppose any plant can produce any product at the same rate. E.g. Plant Atlanta can produce at a rate of 4 million units of Product B, or Product C per week; it can also produce at a rate of 1 million Product As and 3 million Product Ds per week.