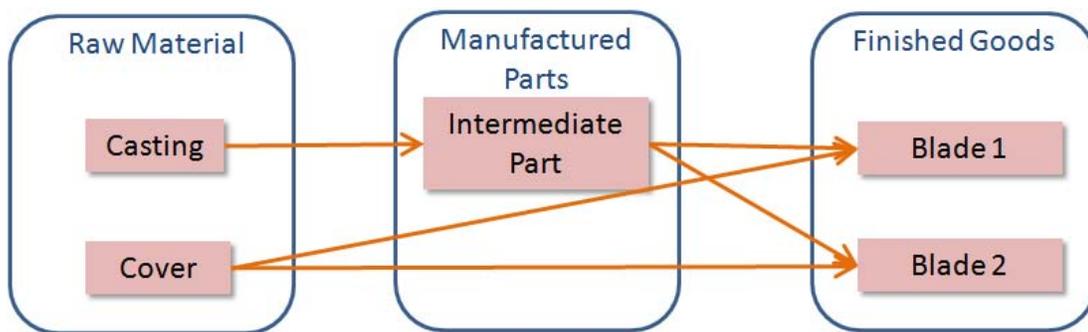# Problem set 3

Due Session 11

There are five questions in this assignment. The first four questions of this assignment are to experiment with the strategic inventory placement model; the last question is based on topics covered in lecture on Session 4.

1. Consider the supply chain shown below:

Suppose we are given the following data for this supply chain:

	Inventory Value	production lead time (weeks)	ave demand (per week)	demand sigma (week)
Blade 1	400	4.0	100	20
Blade 2	425	4.5	150	40
Intermediate part	250	2.0	250	45
Cover	2	1.0	250	45
Casting	75	8.0	250	45

Suppose the service time for the customers for blade 1 and blade 2 is set to 0. Assume that you can use the strategic inventory placement (SIP) model (as discussed in class) for this system. That is we model the inventory at each stage by:

$$z\sigma\sqrt{s_{IN} + L - s_{OUT}}$$

where z is a safety factor (say, z = 2), L is the production or procurement lead time for the stage, s_{IN} is the "inbound" service time, namely the service time from the supplier to the stage, and s_{OUT} is the "outbound" service time, namely the service time that the stage quotes to its customers. (If a stage has multiple suppliers we set s_{IN} as the maximum of the service times quoted by the suppliers).

Suppose each stage quotes the following outbound service times:

	Outbound service time (weeks)
Blade 1	0
Blade 2	0
Intermediate part	10
Cover	1
Casting	8

    a. Determine the safety stock inventory in units and value for each stage (Note: the inbound service times for Cover and for Casting are both zero)

    b. How does the answer in (a) change if the service times for Blade 1 is 2 weeks and for Blade 2 is 3 weeks?

    c. Determine the safety stock inventory in units and value for each stage for the following service times:

	Outbound service time (weeks)
Blade 1	0
Blade 2	0
Intermediate part	0
Cover	0
Casting	0

d. Can you do better than either of the solutions in (a) or (c), assuming the blade service times are zero? What happens to the solution in (c) as you increase the service time for the intermediate part (and reduce its inventory)?

The next three questions entail using the SIPModel software package. With the SIPModel software application you can build a network model of a supply chain. The software has the capability to determine strategic safety stock levels that minimize the total inventory costs across the supply chain. The software can also determine the costs of an existing system based on its current inventory levels.

The following is an overview of how to use the application. There is also a help file with the application.

NOTE – there are many types of inputs and controls in the software – you only need to use the ones described in this note. Also, this is the academic version of the software – as such, it restricts your access to some of the software features.

To Build a Network Model: When you open the application you will find a tool palette on the right hand side of the second row. By using the tools in the tool palette you can build a network. By selecting the "rectangle" you can create stages, or nodes for your network, by clicking in the window. Stages represent a major processing function in the supply chain; examples of stages include final assembly, the procurement of a part, and the shipment of product from the regional distribution center to a retailer. By selecting the blue "arrow" you can then connect stages, by first clicking on the upstream stage and then clicking on the downstream stage; this creates the arcs for the network. The third tool (an "x") can be used to erase either a node or an arc in the network by clicking on it.

You can use the options in the "displayed" menu to view the data associated with each stage in the network. We often use the **icon view**, in which the circle denotes a processing function and the triangle denotes that safety stock is to be held at the stage. If there is no triangle at the stage, then the stage does not hold any safety stock.

Inputs for the Model: From the icon view, one obtains access to an input record by double-clicking with pointer (white arrow) on a stage (node). The following inputs are possible for each stage:

Procurement Time/Production Time -- for raw material stages, the time required to obtain the part from the supplier. For other stages, the time required to produce the product once it has the raw materials to begin production. It includes wait time, processing time and any transportation involved in getting the product from the stage's supplier.

Service Level -- the probability that the stage will fill demand each period within its quoted service time (this cannot be changed in the academic version)

Cost Added – per-unit direct costs added at the stage; typical costs include direct labor and materials.

Stages that do not have any outgoing arcs correspond to demand nodes; each demand node represents one end item. These stages have additional inputs:

Mean Demand - the average per period demand at the stage

Standard Deviation of Demand - the one period standard deviation of demand at the stage

Max FGI Service time - the maximum service time which the stage can quote to its customers.

Decision Variables for the Model

Service Time - The service time for a stage is the amount of time allowed for the stage to fulfill a demand request from an adjacent downstream stage.

As an example, consider a two stage supply chain where stage 2 supplies stage 1. Let us assume that stage 2 has a production lead time of 5 days and immediate access to its raw materials. If the service time for stage 2 is 0, then stage 2 plans to meet all of stage 1's demand directly from inventory; a service time of 0 means that demand in a period will be satisfied in the same period. Therefore, stage 2 must hold enough safety stock to cover its own replenishment time.

If the service time of stage 2 is 5, stage 2 will not hold any inventory but will instead produce product only when it receives a demand signal from stage 1. Stage 2 does not need to hold any finished inventory because the stage can procure and produce the part within its quoted service time.

If the service time is between 0 and 5, this implies that stage 2 must cover some, but not all, of the demand over its replenishment time. For example, if the service time for stage 2 is 2, then stage 2 needs to cover the demand variability over the 3 days (5 - 2 = 3) that it takes to produce additional product once an order is placed on the stage.

What the Software Does

The model determines the service times that will minimize the total cost of the safety stock. To do this, the model has to calculate the required safety stock as a function of the service times.

Alternatively, the user can change the service times in the stages directly; this corresponds to using the software like a calculator, or spreadsheet, to determine the costs of your own stocking strategy. This feature is very useful when trying to find near optimal solutions.

Finally, in each stage there is a check box titled "Bound service time." This feature allows the user to optimize the rest of the system given a bound (lower and/or upper) on the stage's service time. For instance you can use this feature to fix a service time at a stage

by setting the lower bound equal to the upper bound; then you can optimize the rest of the supply chain with this service time fixed. Service times could be fixed based on management discretion or because the resulting solution is easier to implement.

Exercises

To get some familiarity with the model, please do the following exercises.

2. Build the following supply chain depicted below (note – the figures below are from an earlier version of the software, so the 'look' has changed slightly):
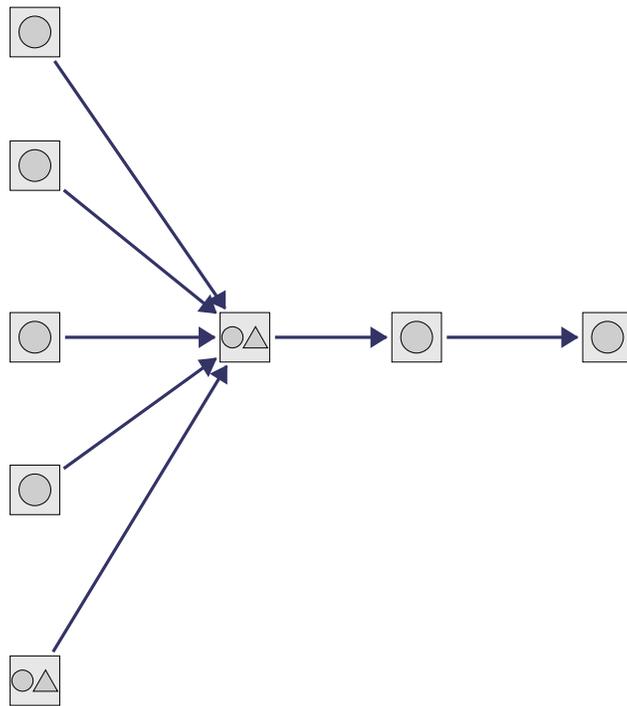
To save space (and allow you to check your work), the figure above depicts the optimal solution. The parameters of interest for the supply chain are:

Stage Name	Production time	Cost added
Camera	60	750
Imager	60	2000
Circuit Board	40	350
Other LT<60	60	150
Other LT>60	150	200
Build/test/pack	8	250
Process order	2	50
Ship to customer	3	0

The mean daily demand (entered at the Ship to customer stage) is 9 units and the standard deviation of demand is 3. The maximum service time to the customer is 5 days, meaning that the company has a maximum of 5 days for the product to arrive to the customer after the order has been placed. Assume the service level is .95 for all stages.

To gain a better understanding of the supply chain, the model depicts the production of a digital camera. The three key inputs are the camera, imager and circuit board; other parts are aggregated and included only to make the cost numbers come out correctly. "Other LT<60" is an aggregation of all components with lead times of less than 60 days; "Other LT>60" is an aggregation of all components with lead times greater than 60 days. The camera is a traditional (35 mm) camera. The circuit board and imager are produced internally; the imager digitizes the traditional camera input and the circuit board processes this picture. For the purposes of this model, the build/test/pack operations have been aggregated. At this stage, the back of the camera is taken off and the imager and circuit board are added. The digital camera is then tested to make sure there are no defects in the imager. Once this is complete, the order is processed through distribution and then the product is shipped UPS to the customer; in this model, customer refers to high end photo shops or computer retailers.

Four different departments are included in the digital-camera supply chain. The imaging group produces the imager, circuit board assembly produces the circuit board, final assembly performs the build/test/pack operations and the process order and ship stages are run by distribution. Finally, safety stock held at a stage corresponds to the functional department holding it. For example, if process order holds safety stock this means that the order can be shipped directly from distribution; i.e., if process order has safety stock then this safety stock is located at the distribution center. If build/test/pack holds safety stock, this means that fully tested digital cameras are being held at the assembly stock vault and are available as soon as distribution asks for product.

a. Optimize this system and review the outputs. Why is there no safety stock held at the process order stage?

b. After looking at the optimal solution, the consultant decides to examine a near optimal solution by setting the service time at the camera, imager and circuit board stages to zero. Why might the consultant recommend this?

c. The company likes the near optimal solution but decides to set the service time at process order to zero. The company likes this because even though it has more inventory than the near optimal policy, it still has less inventory than their existing system; they also like the fact that distribution has inventory they can take right off the shelf. Note that in order to implement this change, you need to reduce the maximum service time to the customer from 5 days to 3 days. .

Assuming this additional requirement that distribution must hold safety stock, would you recommend changing any other stage's stocking policy? What is the rationale for your recommendation?

3. Now, starting from scratch, create the imager supply chain depicted below. This requires closing the current file and choosing new under the file menu.
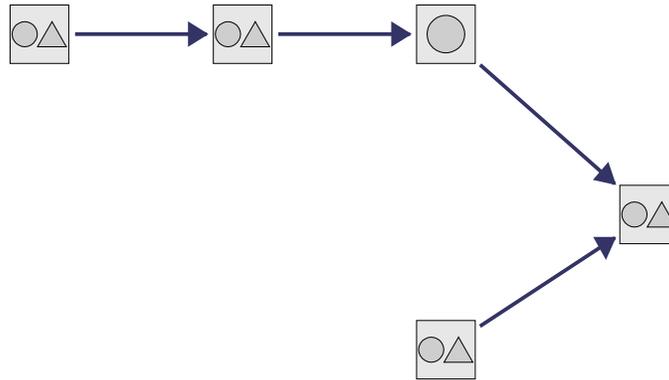
The figure above denotes the current situation in which each stage stocks enough safety stock to decouple each stage from the rest of the supply chain. The parameters of interest for the supply chain are:

Stage Name	Production time	Cost added
Raw Material	130	50
Wafer Fab	30	700
Wafer pkg/test	5	200
Imager base	50	250
Imager assembly	5	500

As before, the mean demand (at imager assembly) is 9 units per day and the standard deviation is 3. The imager assembly's maximum service time is zero; i.e., they want to supply final assembly directly from inventory.

a. Optimize the imager supply chain. Provide some intuition for the optimal solution.

b. What happens to the optimal solution as you reduce the image base lead-time from 50 to 20?

The academic version of the software limits you to networks with at most ten nodes. For question 4, you need to make a small "fix" to the software that expands its capability to fifteen nodes. The instructions are listed after question 4.

4.   Now, starting from either the model you created in problem 1 or problem 2, create the following integrated digital-camera supply chain:
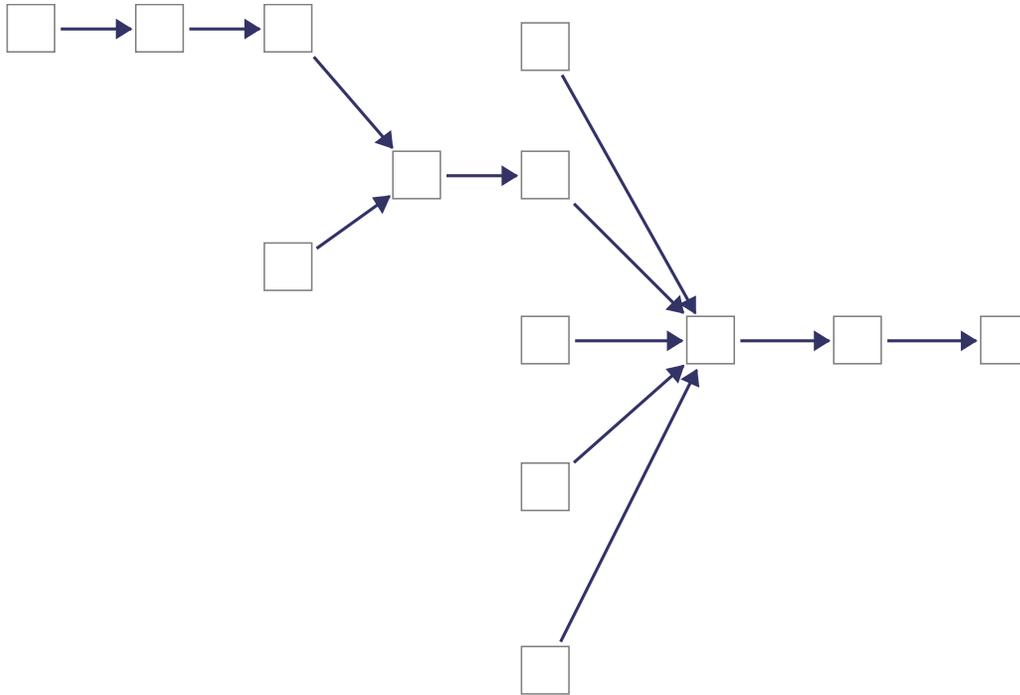
The figure above depicts the production lead-time at each stage. With the exception of the imager base, all of the inputs are still given in the tables from problems 1 and 2. For the imager base, assume the production lead-time is 20 days. As before, the maximum service time that ship to customer can quote is 5 days and the mean demand is 9 and the standard deviation is 3. TO BE CONSISTENT WITH PROBLEM 2, ASSUME THE CIRCUIT BOARD PRODUCTION TIME IS 40 DAYS (NOT 10 DAYS AS IN FIGURE).

The ship to assembly stage acts to link the imager supply chain to the rest of the digital camera supply chain; holding safety stock at ship to assembly corresponds to holding safety stock at the assembly area. The shipment time takes one day and costs $25.

a.   Optimize the supply chain given the constraint that cameras and circuit boards must still quote a service time of zero. How does this solution compare to the combined solution inferred from 2b and 3b? Discuss the differences.

b.   How does the solution and its cost change as you reduce the maximum service time that is quoted by ship to customer? Consider reducing this from 5 days to three days? To one day? To Zero?

Question 5.

Dell procures monitors from Asia for its three distribution centers in the U.S. At the start of each month, each distribution center places an order on the Asian supplier. The lead time to each distribution center is 6 weeks: 4 weeks (equal to one month) in ocean transit from Asia to the west coast port at Long Beach, and then two weeks in rail-transit from Long Beach to the distribution center.

Weekly demand for monitors at the distribution centers is assumed to be normally distributed with the following parameters:

	Mean weekly demand	Standard deviation
DC 1	100	25
DC 2	80	25
DC 3	140	25

Dell is considering two possible changes to this supply chain so as to reduce its inventory requirements.

One change is to use an expedited truck transportation from Long Beach to each of the DC's; this would reduce the transit time on land from two weeks to three or four days.

The second change is to set up a cross-dock operation at Long Beach so that Dell could re-allocate the supply of orders that would go to each DC. That is, when the orders arrive, Dell would have an update on the inventory status at each of the DCs and would use this information to re-route the inventory so as to get the best overall corporate performance.

Suppose that the additional operating cost for each change is the same.

a.   Which change would lead to the greatest reduction in inventory? Why? You can make additional assumptions (within reason) as needed.

b.   What is the benefit of making both changes? Are the changes synergistic or competing?

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