Matching Supply with Demand: An Introduction to Operations Management

Solutions to End-of-Chapter Problems

(last revised February 2012; make sure to visit www.cachon-terwiesch.net for the latest updates, excel files, ppt files and other information)

Chapter 7 – Batching and Other Flow Interruptions

Q7.1 Window Boxes

a) The production cycle consists of setup to produce part A (120 minutes), produce A (1 minute per part), setup to produce B (120 minutes), and produce B (1 minute for two sides). The total setup time in this production cycle is 240 minutes. The processing time for the two components is 2 minutes. There are 360 component sets produced in each production cycle. So the capacity of the stamping machine is 360 / (240 + 2 x 360) = 0.375 units per minute.

b) We want to choose a batch size so that the capacity of the stamping process is the same as the capacity of the assembly process. The capacity of the assembly process is (1/27 units per minute) x 12 workers = 12/27 units per minute. The desired batch size is the found using the following equation: batch size = (flow rate x setup time) (1- flow rate x processing time). Hence, batch size = (12/27 x 240)/(1-12/27 x 2) = 960.

Q7.2 PTest

a) PTest can test 300 samples in 12*300/60+30 = 90min = 1.5hour. The capacity is 300 samples/1.5hours = 200 samples/hour.
b) The smallest batch size that achieves a flow rate of 2.5 samples per minute is 2.5 * 30/(1-12/60*2.5) = 150 samples.
c) The number of basic tests per minute = 70 / (15/60 * 70 + 1.5*30+20) = 70/82.5 = 0.848

Q7.3 Gelato

a) Each batch consists of a set of three flavors. The total setup time is ¾ + ½ + 1/6 = 17/12 hours. The desired flow rate is 10 + 15 + 5 = 30 kgs/hr. The processing time is 1/50 hrs/kg. The desired batch size for the set of three is 30 x 17/12 / (1- 30 x 1/50) = 106 kgs.
b) Fragola is 10/30ths of demand, so produce (10/30) x 106 = 35.33 kgs of fragola
c) Demand for chocolato is 15 kgs per hour and production occurs at the rate of 50 kgs per hour. So while chocolato is being produced, it increases inventory at the rate of 50 – 15 = 35 kgs per hour. Chocolato is 15/30ths of demand, so the chocolato batch is (15 / 30) x 106 = 53 kgs. At the rate of 50 kgs per hour, chocolato is produced for 53 / 50 = 1.06 hours. So maximum inventory of chocolato is 1.06 hr x 35 kgs/hr = 37.1 kgs.

Q7.4 Two-step

a) Capacity of step B is 5 / (9 + 0.1 x 5) = 0.53 units per minute. The first activity makes 1 unit per minute, so the bottleneck is the second step.
b) The desired flow rate is 1 unit per minute because that is the capacity of step A. Recommended batch size = 1 x 9 / (1 - 1 x 0.1) = 10
c) After 9 minutes, the process can resume and approximately produces one unit every 1 minute. (The first unit takes 1.1 minutes, while all others take 1 min, but this will have a small impact on the calculation.) So the target batch size is 0.82 x 9 / (1 - 1 x 0.82) = 41. If you account for the 1st unit taking slightly longer, the batch size should be rounded up to 42.

Q7.5 Simple Set-Up

(a) First, we calculate the process capacity at each step using the formula for process capacity with batching: B / S + T_b where B = batch size, S = set-up time, and T_b = time to process the entire batch. So, the first step has a process capacity of 50 units / (20 minutes + (1*50) minutes) = .714 units/minute = 42.86 units/hour. The second step has a process capacity of 50 units / (2*50) minutes = 30 units/hour. The third step has a process capacity of 50 units / (1.5*50) minutes = 40 units/hour. Therefore, the process capacity of the entire process = *30 units/hour*.

(b) The only step that is dependent on the batch size is Step 1. With a batch size of 10 units, the process capacity of the first step becomes 10 units / (20 minutes + (1*10) minutes) = 10 units / 30 minutes = 20 units/hour. Therefore*, Step 1* becomes the bottleneck.

(c) If the batch size is 50 parts, and the batch must stay together, then in order to process 20 parts, a batch of 50 parts must be processed through Step 1 and Step 2. The total time to process through Step 1 = 20 minutes for set-up + 50 minutes for processing = 70 minutes. The total time to process the batch through Step 2 = 100 minutes. So, the batch takes 170 minutes through the first two steps. At Step 3, we merely need to process the 20 parts. Processing 20 parts through Step 3 takes 30 minutes. Under these conditions it takes a total of *200 minutes* to process 20 parts.

(d) At Step 1, there is a set-up time of 20 minutes. So, the first part takes a total of 20+1+2+1.5 = 24.5 minutes to complete. We can now use our formula for the total time to process Q units using Q = 20 and R= 30 units/hour or 20 units/40 minutes. Thus, under these conditions it takes 24.5 + (19 / 20/40) = *62.5 minutes* to process 20 parts.

(e) In order to determine an optimal batch size, we set the process capacity of Step 1 (the only step dependent on batch size) equal to the process capacity of the bottleneck capacity. The bottleneck capacity is 30 units/hour, or 1 unit every 2 minutes. So, we solve for B using the following formula:
1 unit / 2 minutes = B / (20 minutes + B minutes)

B = 20 units. If B < 20 units, then Step 1 becomes the bottleneck and the capacity of the entire process decreases.

Q7.6 Set-Up Everywhere

(a) Capacity = B / S + T_b = 35 parts / (30 minutes + (0.25*35) minutes) = .903 units/minute = *54.19 units/hour*

(b) Step 2 is never the bottleneck because its processing time, 20 + 0.20B, is always less than Step 1's processing time, 30 + 0.25B, for any positive value of B. So the task can be simplified to determining for what values Steps 1 and 3 are the bottleneck. The processing time for the two steps are equal when 30+0.25B = 45+0.15B, or when B=150. For batches smaller than 150 parts, Step 3 is the bottleneck. For batches larger than 150 parts, Step 1 is the bottleneck.

Q7.7. JCL

a. Capacity of a step is given by Batch Size/ (Set-Up-Time + Batch-Processing-Time). Using this formula, the capacity of the three steps can be calculated as:

Deposition: 100/ (45+0.15*100) = 1.67 units/min = 100 units/hour
Patterning: 100/ (30+0.25*100) = 1.82 units/min = 109 units/hour
Etching: 100/ (20+0.2*100) = 2.5 units/min = 150 units/hour

Clearly the bottleneck is the "deposition" step and it determines process capacity.

b. Since the batch has to stay together in the first two steps, time taken is given by

Deposition: 45 min + 0.15 min/unit * 100 units = 60 min
Patterning: 30 min + 0.25 min/unit * 100 units = 55 min

So the batch takes 115 min through the first two steps. At step 3, only 50 units need to be processed, and time taken is 20 min + 0.20 min/unit * 50 units = 30 min. Total time taken is hence 115 + 30 = 145 min = 2 hours 25 min

c. If batch size is B, then processing time of step 3 is 20 + 0.20B which is always lesser than the processing time of step 2, 30 + 0.25B, for a positive value of B. Hence step 3 can never be the bottleneck.

d. Under the new technology, the process capacity of step 1 is no longer dependent on batch size and is = (1/ 0.45 min/unit) * (60 min/hr) = 133.33 units/hour. This is clearly the maximum overall process capacity that can be targeted.

Given that step 3 can never be the bottleneck, the maximum overall process capacity of 133.33 units/hour can be achieved by choosing a batch size for which step 1 is the bottleneck. So if B is the batch size for which step 1 is the bottleneck, then we have B/ (30 + 0.25B)>= 1/0.45. Solving for B, we get B>=150.

Q7.8 Kinga Doll

a. The process capacity of molding = 500 / (15+(.25*500)) = 3.57 dolls/minute = 214.9 dolls/hour.
The process capacity of painting = 500 / (30+(.15*500)) = 4.76 dolls/minute = 285.7 dolls/hour.
The process capacity of dressing = 1/.3 = 3.33 dolls/minute = 200 dolls/hour.
Therefore, the process capacity = 200 dolls/hour.

b. The batch of 500 spends 15 + (.25*500) = 140 minutes in molding, 30 + (.15*500) = 105 minutes in painting and .3*500 = 150 minutes in dressing. Therefore, the time to complete a batch of 500 dolls = 140+105+150 = 395 minutes or 6 hours 35 minutes.

c. Setting the process capacity of molding to 3.33 dolls/minute, the optimal batch size for molding = 300 dolls.
Setting the process capacity of painting to 3.33 dolls/minute, the optimal batch size for painting = 200 dolls.
Therefore, the optimal batch size = 300 units.

d. The flow rate is the minimum of the process capacity, which is 3.33 dolls/minute or 200 dolls/hour, and demand. We know demand = 4000 dolls/week, with a 40-hour work week. Therefore, the demand = 100 dolls/hour, which is less than the process capacity. Therefore, the current flow rate = 100 dolls/hour or 1.67 dolls/minute.
Setting the process capacity of molding to 1.67 dolls/minute, the optimal batch size for molding = 42.85 or 43 dolls.
Setting the process capacity of painting to 1.67 dolls/minute, the optimal batch size for painting = 66.7 or 67 dolls.
Therefore, the optimal batch size is 67.

Q7.9 Bubba Chump Shrimp

(a) For the first 3 hours, the desheller can process 400*3=1200 lbs of shrimp. However, only 300 lbs can be processed in the 4^{th} hour because the machine is stopped for 15 minutes. Therefore, in a 4-hour period, 1500 lbs of shrimp are processed by the desheller. Since there are three 4-hour periods in a 12-hour workday, the daily processing capacity is 1500*3 = 4500 lbs per day.

(b) The daily process capacity of the deveiner is 360 lbs/hr * 12 hrs/day = 4320 lbs per day.

(c) When the system is operating, the deveiner is the bottleneck, limiting output to 360 lbs/hr. However, for 15 minutes every 4 hours, the desheller is the bottleneck since there are no inventory buffers, limiting output to 0 lbs/hr. Consequently, the plant will operate for 11 hours and 15 minutes of the 12-hour workday at a rate of 360 lbs/hr. Daily processing capacity is 11.25 hrs * 360 lbs/hr = 4050 lbs per day.

(d) First, we are given the information that the time to fill the system is negligible, so we do not need to account for this time. Five trucks bring a total of 5*1000 lbs/truck = 5000 lbs of shrimp. However, the process capacity is 4050 lbs of shrimp. Therefore, 5000 lbs – 4050 lbs = 950 lbs of shrimp must be wasted.

Q7.10 Catfood

(a) Holding costs are $0.50 * 15% / 50 = 0.0015 per can per week. Note, each can is purchased for $0.50, so that is the value tied up in inventory and therefore determines the holding cost. The EOQ is then $\sqrt{\frac{2*7*500}{0.0015}} = 2160$

(b) The ordering cost is $7 per order. The number of orders per year is 500/EOQ. Thus, order cost= $\frac{7*500}{EOQ} = 1.62$ \$/week=81\$/year

(c) The average inventory level is EOQ/2. Inventory costs per week are thus 0.5*EOQ*0.0015 = $1.62. Given 50 weeks per year, the inventory cost per year is $81

(d) Inventory turns=Flow rate / Inventory
Flow Rate= 500 cans per week
Inventory=0.5 * EOQ
Thus, Inventory Turns= R / (0.5*EOQ) = 0.462 turns per week = 23.14 turns per year

Q7.11 Beer Distributor

The holding costs are 25% per year=0.5% per week=8*0.005=$0.04 per week

(a) EOQ= $\sqrt{\frac{2*100*10}{0.04}} = 223.6$

(b) Inventory turns = Flow Rate / Inventory = 100 x 50 / (0.5 x EOQ) = 5000 / EOQ = 44.7 turns per year

(c) Per unit inventory cost = $\sqrt{\frac{2*0.04*10}{100}} = 0.089\$/unit$

(d)You would never order more than Q=600
For Q=600, we would get the following costs: 0.5*600*0.04*0.95 + 10*100 / 600 = 13.1
The cost per unit would be 13.1/100=$0.131

The quantity discount would save us 5%, which is \$0.40 per case. However, our operating costs increase by \$0.131 - 0.089 = \$0.042. Hence, the savings outweigh the cost increase and it is better to order 600 units at a time.

Q7.12 Millenium Liquors

The fixed cost of refrigeration can be ignored because that cost does not change as we vary our order quantity.

(a) weekly holding cost 15%/50 per week * 120 \$/case = 0.36 \$/week

(b) The ordering cost is \$290+\$10 = \$300. EOQ= $\sqrt{\frac{2*300*45}{0.36}}$ = 273.9 cases per order

(c) We would get slightly lower ordering costs, which results in more frequent orders and lower inventory

Q7.13 Powered by Koffee

The holding costs are \$1.50 per month (\$1 storage and \$0.50 capital)

(a) EOQ= $\sqrt{\frac{2*85*50}{1.5}}$ = 75.27

(b) Order frequency: (12 * 50) / EOQ = 8 times per year

(c) Average inventory is EOQ/2. So months of supply = (EOQ / 2) / 50 = 0.75 months

(d) inventory costs per month = (EOQ / 2) * 1.50 = 56.46 \$ / month

(e) The monthly holding cost per bag is \$1 + 0.02 x 20 = 1.4. Annual purchase quantity is 12 x 50 = 600 bags. The average inventory will be 600 / 2 = 300, and so the monthly holding cost is 300 x \$1.4 = \$420. The yearly holding cost is 12 x \$420 = \$5040. The annual purchase cost is 600 x \$20 = \$12,000. The total annual cost of this option is \$12,000 + \$500 + \$5040 = \$17,540.

The current system operates at costs of 12* $\sqrt{2*85*50*1.5}$ +600 x 25=16,355

Thus, the original system is cheaper.