ISYE 6201: Manufacturing Systems
Spring 2016
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Final Exam
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Name: SOLUTIONS

Answer the following questions **(8 points each)**:

1. In class we showed that, under certain conditions, the optimal order quantity Q^* for the classical news-vendor model with *normally* distributed demand might actually decrease in response to an increase of the variability of the demand (while the mean demand remains constant). Consider now a more service-oriented analysis of the aforementioned problem where instead of seeking to minimize the expected total cost, we select the order size $\bar{Q}$ as the minimum order size that guarantees a certain probability of meeting in its entirety the demand to be experienced during the upcoming season. Under such an analysis, is it still possible that the selected order size $\bar{Q}$ might decrease in response to an increase of the variability of the demand distribution (while, again, the mean demand remains constant)?

[✓ (a) YES] (b) NO

Explain your answer.

The considered order size $\bar{Q}$ is specified by the equation $F(\bar{Q}) = p$, where p is the sought probability of meeting the entire experienced demand. As discussed in class, for normally distributed demand, the solution to the above equation is $\bar{Q} = \mu + z_p \sigma$, where

* μ is the mean demand;
* σ is the st. deviation of the demand;
* z_p is the p-quantile for the $N(0,1)$ distribution.

Then, it is clear that if $p < 0.5$, then $z_p < 0$, and increasing σ would decrease $\bar{Q}$.

Of course, in most practical cases, $p > 0.5$ and an increase of σ will lead to an increase of $\bar{Q}$.

One way to understand the rather counter-intuitive result in the case that $p < 0.5$, is by noticing that this requirement is not very difficult to satisfy in the first place, and when demand volatility increases the probability that it will get some of its lower values becomes higher.

2. Provide some conditions under which "demand chasing" can be a viable strategy for meeting the expected demand.

"Demand chasing" implies adjusting our internal production capacity so that it matches the expected demand at each period of the planning horizon. In traditional production planning settings this implies the adjustment of the regular labor capacity through the continuous hiring and firing of workers. For this to be possible, the required labor should be rather unskilled, and the economic and social implications of lay offs not very severe. In class we provided some examples of certain economic sectors where these conditions might be satisfied through some natural seasonality in the overall "production" activity involved. These examples included the support of certain agricultural operations, like the collection of certain crops, the staffing of certain businesses that operate only in certain seasons over the year like the businesses at certain vacation spots and campuses, etc.

3. Provide *two* elements of non-linear behavior that may arise in the context of aggregate planning.

* fixed costs

* non-linearities due to economies of scale (e.g., like quantity discounts)

4. The main reason for the use of lot-sizing heuristics instead of the Wagner-Whitin algorithm in the context of the MRP explosion calculus is the computational simplicity of these heuristics.

(a) TRUE [✓ (b) FALSE]

Explain your answer.

The most important reason for the use of these heuristics these days is because they do give performance comparable to the W-W algorithm (at least the SM, LUC and PPB heuristics) and at the same time, they are less sensitive to possible variations of the demand especially in the furthest periods of the planning horizon. This lack of sensitivity translates to a higher robustness and stability of these plans in their earlier periods of the underlying planning horizon, ~~and much to~~ which renders these plans practically implementable.

5. Discuss the meaning and the role of proactive demand management in the context of modern production systems.

Proactive demand management implies the current efforts not only to effectively predict / forecast future demand, but also influence it to their advantage through promotional, advertising and pricing strategies.

These strategies have been facilitated substantially during the last 15-20 years through the emerged IT platforms that enable these companies to monitor much more effectively their operational environment, and to connect more directly to their customers.

Proactive demand management is especially important for companies that try to operate with a constant capacity, like those that utilize "pull"-type of production systems.

Problem 1 (20 points): The Paris Paint Company is in the process of planning its labor force requirements and (aggregate) production levels for the next four quarters. The marketing department has provided production with the following forecasts of (aggregate) demand for Paris Paint over the next year:

Quarter	Demand Forecast (in thousands of gallons)
1	380
2	630
3	220
4	160

Currently there are 280 employees with the company. Also, according to the company policies, employees are hired for at least one full quarter, and the corresponding hiring costs amount to \$1,200 per employee. Firing costs are \$2,500 per employee. Inventory costs are \$1.00 per gallon per quarter. It is estimated that one worker produces 1,100 gallons of paint each quarter.

Finally, currently Paris has 80,000 gallons of paint in inventory and would like to maintain an inventory of 20,000 gallons throughout the coming year.

i. (10 pts) Determine the "demand chasing" plan that meets the forecasted quarterly demand with zero inventories by adjusting the company labor level every quarter, and the corresponding overall cost.

ii. (10 pts) Also, determine an alternative plan (and the corresponding cost) that seeks to meet the expected demand by maintaining a constant workforce level throughout the year. The level of this workforce should be the minimum possible that will allow the company to meet its quarterly demand in a timely manner, possibly building anticipatory inventories in the process.

(i) Based on the provided information, the net demand for each quarter is

$< 380-80+20=320, \quad 630, \quad 220, \quad 160 >$

The 20 thousands of gallons added in period 1 is meant to satisfy the posed safety stock requirement.

Then, the required labor to meet these requirements every period is:

$\lceil 320/1.1 \rceil = 291; \quad \lceil 630/1.1 \rceil = 573; \quad \lceil 220/1.1 \rceil = 200;$

$\lceil 160/1.1 \rceil = 146$

With 280 employees at the current time, the above labor requirements imply the hiring of 11 and 282 workers in periods 1 and 2, and the firing of 373 and 54 workers in periods 3 and 4.

(ii) The next calculations provide the minimal number of required workers to meet the entire net demand of x consecutive quarters, for x = 1, 2, 3 and 4, and the workers working full time at each quarter:

$$\left\lceil \frac{220}{1.1} \right\rceil = 291; \quad \left\lceil \frac{320+630}{2\times 1.1} \right\rceil = 432; \quad \left\lceil \frac{320+630+220}{3\times 1.1} \right\rceil = 355$$

$$\left\lceil \frac{320+630+220+160}{4\times 1.1} \right\rceil = 303$$

Hence, if we want to meet all the demand without any stockouts we need to employ 432 workers. These workers will produce 475 thousands of gallons in each of the first two quarters, building also an anticipatory inventory of 155 thousand gallons in quarter 1, and then produce the required amounts of 220 and 160 thousand gallons in quarters 3 and 4. Apparently there will be considerable underutilization of these employees in the last two quarter

Problem 2 (20 points): Consider a single-server inspection station that monitors the output of an automated production process that produces parts at a deterministic rate of 120 parts per hour. The basic inspection of a part lasts 1 min but parts that are found to be defective from this first inspection need some further handling that requires an additional time which is normally distributed with a mean of 2 min and st. dev. 0.5 min. Currently it is estimated that the defective parts constitute the 5% of the arrivals.

i. (10 pts) What is the minimum number of inspectors that must employed in this station so that the expected cycle time of the parts at this station is no more than 2 minutes?

ii. (5pts) What is the average WIP at this station that results from your response in part (i)?

iii. (5pts) What is the "stability margin" for this station that results from your response in part (i), i.e., what is the maximum increase of the percentage of defects in the arrival stream that maintains a stable operation for the station?

(i) The processing time for this workstation is a r.v. T that is a mixture of the following two distributions:

$$T \sim \begin{cases} 1 \text{ min} & \text{w.p. } 0.95 \\ N(3, 0.5^2) & \text{w.p. } 0.05 \end{cases}$$

Hence, $E[T] = 0.95 \times 1 + 0.05 \times 3 = 1.1 \text{ min}$

For stability, we need $r E[T] < m$ where m is the number of servers (i.e., inspectors). Hence,

$m > \frac{120}{60} \times 1.1 = 2.2 \Rightarrow m_{min} = 3.$

To compute CT, we need to compute u for the considered m, and the SCV[T]. For the latter, we have:

$E[T^2] = 0.95 \times 1 + 0.05 \times (0.5^2 + 3^2) = 1.4125$

$Var[T] = E[T^2] - E^2[T] = 1.4125 - 1.1^2 = 0.2025$

$SCV[T] = Var[T] / E^2[T] = 0.2025 / 1.1^2 = 0.1673$

Also, for $m = 3$: $u = \frac{rt}{m} = \frac{120 \times 1.1/60}{3} = 0.733$

Then:

$$CT(3) = \frac{0.1673}{2} \cdot \frac{0.733^{\sqrt{2(3+1)}-1}}{3(1-0.733)} \cdot 1.1 + 1.1 = 1.165 \text{ min} < 2 \text{ min}$$

(ii) From Little's law: $WIP = r.CT = \frac{120}{60} \times 1.165 = 2.33$

(iii) Let p denote the percentage of the defective parts. For stability, we need:

$$\frac{2}{60}\left[(1-p)+3p\right] \leq 3 \Rightarrow 2p \leq 1/2 \Rightarrow p \leq 1/4.$$

Problem 3 (20 points): A certain item X constitutes a major subassembly for two SKUs, A and B, that are offered to the market by the producing company. The production plans for the two parent items A and B over an 8-week planning horizon, in terms of planned order releases, are as follows:

item	1	2	3	4	5	6	7	8
A				40			40	
B			20	30	25	20	20	30

In addition, there is an external demand for X of 20 units per week.

The company currently holds an inventory of 110 units of X, while an initiated lot of 50 parts is expected to reach the company stock in the first week.

i. (10 pts) Compute the *net* requirements for X over the considered planning horizon of 8 weeks.

ii. (10 pts) The company accountants estimate that it costs \$1.00 to carry one unit of X in the company stock for one week, and \$75.00 to initiate the production of a new lot of this item. Furthermore, the shop floor managers of the company estimate that a reasonable nominal production lead time for a new lot of X is 2 weeks. Combine this information with your results from part (i) in order to compute the production plan for X over the considered planning horizon that will result by the application of the *Silver-Meal* heuristic. Communicate your results as a vector of *planned order releases* over the considered planning horizon.

(i)

Period	1	2	3	4	5	6	7	8
Gross Reqs	20	20	40	90	45	40	80	50
Sch. Recpts	50							
Inv. Projection 110	140	120	80					
Net Reqs				10	45	40	80	50
Planned Receipts				55		40	130	
Planned Releases		55		40	130			

see next page ⇐

Application of the SM heuristic on the net requirements

	Periods	OC	HC	TC	TC /period
Group	[4	75	–	75	75
	5	75	45	120	60
	6	75	45+80	200	66.67
	[6	75	–	75	75
	7	75	80	155	77.5
	[7	75	–	75	75
Group	8	75	50	125	62.5