

ISYE 3104: Manufacturing Systems
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Midterm Exam I
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Name: SOLUTIONS

Answer the following questions (8 points each):

1. In a commoditized market, companies are competing primarily on the basis of their quality image.

(A) TRUE (B) FALSE

Please, explain your answer.

Commodities are products for which all the quality attributes have pretty much crystallized and converged across all producing companies. At this stage companies compete primarily by quoting competitive prices (cost leadership).

2. In which of the four stages of the product life cycle is *demand forecasting* most critical?

Please, explain your answer.

Demand forecasting is important in, both, the growth and the maturity phase.

In the former phase companies must track a growing demand in a way that will allow them to maintain a responsive operating and at the same time will not inflate their operational costs due to excessive capacity and production.

Similar requirements for establishing and maintaining responsiveness and cost effectiveness through pertinent demand forecasting exist also in the maturity phase. However, since demand is much stabler in this phase, forecasting is not as challenging as in the growth phase.

⇒ In that sense we can say that demand forecasting is most critical in the growth phase.

3. Discuss the importance of *modularity* in the operations of modern corporations.

Modularity means the composition of a product or a function by well defined, standardized, and therefore, ^{easily} exchangeable / replaceable components (or modules).

In class we discussed how ^{product} modularity, combined with the concept of combinatorial customization, enable modern corporations to offer their customers ~~offer~~ a great variety of end-product configurations, by composing / assembling them from components with well-defined, standardized and easily exchangeable options.

Along similar lines, modularity allows companies ⁽ⁱ⁾ to introduce easily and fast new product concepts while reusing and mingling components from their existing product portfolio, ⁽ⁱⁱ⁾ manage more efficiently the inventories of these components by taking advantage of the "pooling effect" that results from the aggregation of the demand of the end-items that involve these components, and ⁽ⁱⁱⁱ⁾ communicate and interact more efficiently with the upstream parts of the supply chain that might provide these components.

On the other hand, application of the notion of modularity to the production process itself, enables an easier design, expansion and reconfiguration of production shop floors.

4. In the lectures it was shown that, in the worst case, the heuristic of Power-of-2-order-intervals will inflate the total annual cost of any particular product by a factor of about 1.06. Imagine an implementation of this heuristic where the "threshold" point that splits the interval between any two consecutive powers 2^k and 2^{k+1} is not the value $\sqrt{2} \cdot 2^k$, that was computed in the lectures, but the middle point of that interval. Compute the worst-case performance of this alternative implementation. Please, show clearly the entire logic of your computation.

The middle point between 2^k and 2^{k+1} is

$$\frac{2^k + 2^{k+1}}{2} = 2^k \left(\frac{1}{2} + 1 \right) = 1.5 \cdot 2^k > \sqrt{2} \cdot 2^k$$

Hence, in this new splitting of the interval $(2^k, 2^{k+1})$ is defined by the case where $T^* = (1.5 \cdot 2^k)^-$ and therefore it must be replaced by $T = 2^k$.

Then, using the cost sensitivity formula presented in class, we get:

$$\begin{aligned} \frac{1}{2} \left[\frac{T}{T^*} + \frac{T^*}{T} \right] &= \frac{1}{2} \left[\frac{2^k}{1.5 \cdot 2^k} + \frac{1.5 \cdot 2^k}{2^k} \right] = \\ &= \frac{1}{2} \left[\frac{1}{1.5} + 1.5 \right] = 1.08\bar{3} \end{aligned}$$

i.e., now the worst-case inflation of the cost w.r.t. to its optimal value is 8.33%

5. The demand forecasted over a six-period planning horizon for an inventoried item that is procured according to an optimized, uncapacitated, dynamic lot sizing policy, is given by the following sequence (in units of product):

< 1000, 1150, 1200, 950, 850, 1000 >

The current on-hand inventory is 100 units. The procurement plan computed based on the above information is as follows:

< 2850, 0, 400, 2800, 0, 0 >

Looking at the above numbers we can conclude that somebody has ... messed up!

(A) TRUE (B) FALSE

Explain your answer.

This plan meets effectively all the demand but it violates the W-W property, which is the key result for the development of an optimized solution for the uncapacitated dynamic lot sizing problem. In particular, the proposed plan carries inventory from period 2 to period 3 and at the same time places a new order at period 3.

Problem 1 (40 points): A specialty coffee house sells Colombian coffee at a fairly steady rate of 280 pounds annually. The beans are purchased from a local supplier for \$2.40 per pound. The coffee house estimates that it costs \$45 in paperwork and labor to place an order for the coffee, and holding costs are based on a 20% annual interest rate.

- (10pts) Assuming that a continuous review policy is applied, determine the optimal order quantity for this type of coffee.
- (10pts) What is the replenishment interval for the quantity that you computed in part (1)? Please, provide your response in weeks.
- (10pts) The considered coffee is procured from the aforementioned supplier together with some other products and in an effort to consolidate its replenishments across this set of products, the coffee house is thinking of switching to a "Power-of-2-order-intervals" scheme that utilizes the week as the basis time unit. What should be the replenishment interval for the considered coffee under this new scheme?
- (10pts) What is the increase of the combined ordering and holding annual cost for the considered coffee that will result from the policy switch that is suggested in part 3 above?

1) Based on the problem data:

$$A = 45 \text{ \$/order}; \quad h = 0.2 \times 2.40 = 0.48 \text{ \$/pound \times yr};$$

$$D = 280 \text{ pounds/yr}$$

$$\text{Hence, } Q^* = \sqrt{\frac{2AD}{h}} = \sqrt{\frac{2 \cdot 45 \cdot 280}{0.48}} = 229.13 \text{ pounds}$$

$$2) \quad T^* = \frac{Q^*}{D} = \frac{229.13}{280} \approx 0.82 \text{ yrs}$$

Assuming 52 weeks per yr, we get

$$T^* = 0.82 \times 52 \approx 42.64 \text{ weeks.}$$

3) From (2), we have that $T^* \in (32 = 2^5, 64 = 2^6)$

$$\text{Also } \sqrt{2} \cdot 32 = 45.25 > T^*$$

Hence, we must use $T = 32$ weeks

4) Using the sensitivity formula, we get that replacing T^* by T will lead to a cost inflation of

$$\frac{1}{2} \left[\frac{42.64}{32} + \frac{32}{42.64} \right] \approx 1.0415$$

To get the cost increase in absolute terms, notice that the optimal ^{annual} ordering plus holding cost is:

$$\frac{AD}{Q^*} + \frac{hQ^*}{2} = \frac{45 \times 280}{229.13} + \frac{0.48 \times 229.13}{2} = 109.98 \text{ \$/yr}$$

Combined with the previous result, this last calculation gives an annual increase of

$$109.98 \times (1.0415 - 1.00) = 4.56 \text{ \$}$$

Problem 2 (20 points): The management of a local newspaper that is sold at \$1.50 per copy hired a leading consultant, at a rate of \$1,000 per day, in order to assist them to optimize their daily production volume. According to the running policies, the paper was produced at a volume of 70,000 copies per day. After working hard for three weeks, studying the company operations and its distribution system, the consultant came to the conclusion that the production cost for the company is \$0.60 per copy, while the daily demand of the newspaper can be approximated pretty accurately by a uniform distribution over the interval [50,000, 100,000]. He also suggested that the company should increase its daily production by 10,000 copies.

1. (10pts) Based on the above information, what must be the estimated salvage value for the unsold copies?
2. (10pts) How long will it take before the expected gains of the company that result from the aforementioned study will exceed the cost of the study itself?

(1) From the problem description, we have that

$$g(Q^*) = \frac{80000 - 50000}{100000 - 50000} = \frac{3}{5} = 0.6 \quad (1)$$

But from the newsvendor theory we know that

$$g(Q^*) = \frac{c_s}{c_o + c_s} \quad (2)$$

where c_s is the shortage cost per unit and c_o is the overage cost per unit. In the considered

case,

$$\begin{aligned} * \quad c_s &= \text{the lost profit per unsold unit} = \\ &= \$1.50 - \$0.60 = \$0.90 \quad (3) \end{aligned}$$

$$\begin{aligned} * \quad c_o &= \text{unit production cost} - \text{unit salvage value} \\ &= 0.60 - x \quad (4) \end{aligned}$$

Combining (1), (2), (3) and (4), we get:

$$\frac{0.9}{0.6 - x + 0.9} = 0.6 \Leftrightarrow 1.5 = 1.5 - x \Leftrightarrow x = 0.$$

(2) From the results of part (1), the expected daily cost reduction by increasing production from 70,000 to 80,000 copies per day can be computed as follows:

$$\begin{aligned} & 0.6 \int_{50,000}^{70,000} (70,000 - x) \frac{1}{50,000} dx + 0.9 \int_{70,000}^{100,000} (x - 70,000) \frac{1}{50,000} dx \\ &= 0.6 \int_{50,000}^{70,000} (70,000 - x) \frac{1}{50,000} dx + 0.9 \int_{80,000}^{100,000} (x - 80,000) \frac{1}{50,000} dx \end{aligned}$$

$$= \dots = 1500 \text{ \$/day}$$

Since the consultants worked for ~~3~~ 15 days at a rate of \$1,000 per day, their total fee was \$15,000.

From the previous result, it follows that the average number of days for recovering this cost is $\frac{15000}{1,500} = 10$.