

# Operations Management

## Midterm 1

30/3/2011

Duration 2h30m

Remember the following tips:

- Budget your time. Skim through the exam before starting.
- Show all your work to allow us to give you partial credit if appropriate.
- Answer groups in separate pages and please write down your name in all pages.

**Good Luck!**

### Group 1 (75 points)

a) Classify each one of the following statements as True (T), False (F), or Undetermined (U). Justify briefly your answer (maximum 2 lines).

- a1) (5 pts) The EOQ (or optimal Q) refers to the order quantity for which the annual holding costs and the annual ordering costs are the same.
- a2) (5 pts) The hamburgers production system in fast-food chains like McDonalds and Burger King represents a good example of a 'jobshop' in the services context.
- a3) (5 pts) In a product/process matrix, as we move from 'project' to 'continuous process', we typically will encounter lower volumes, less vertical integration, more resource flexibility, more customer involvement and less capital intensity.
- a4) (5 pts) Exponential smoothing is a special type of weighted moving average.
- a5) (5 pts) In an optimal fixed-quantity system with backorders, if  $b=H$ , then  $2B^*=Q^*$

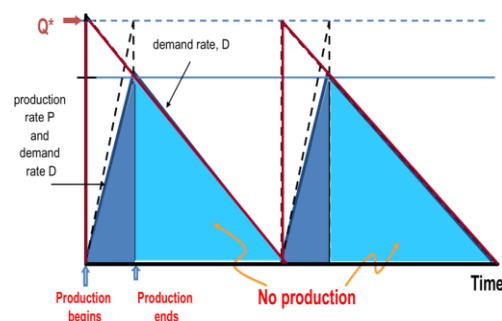
b) (10 pts) Briefly describe the relationship between MRP (Material Requirements Planning), APP (Aggregate Production Planning) and forecasting.

c) (10 pts) Show that in fixed-quantity system with backorders, the economic order quantity can be two times the amount of an equivalent model without backorders, if the holding cost is three times the backorder cost?

d) (10 pts) The IRS Department writes regulations in accord with laws passed by Congress. On average the department completes 300 projects per year. The Wall Street Journal reports that, as of October 11 2009, the number of projects currently "on the Department's plate" is 588. Nevertheless the department head claims that average time to complete a project is under 6 months. Do you agree? Why?

e) (20 pts) The figure illustrates the POQ model. If  $D$  is the annual demand,  $P$  the annual production rate,  $C_s$  cost of placing an order,  $C_h$  annual inventory cost per unit, please develop and explain the expressions for a) maximum stock level; b) total annual costs; c) optimal order quantity

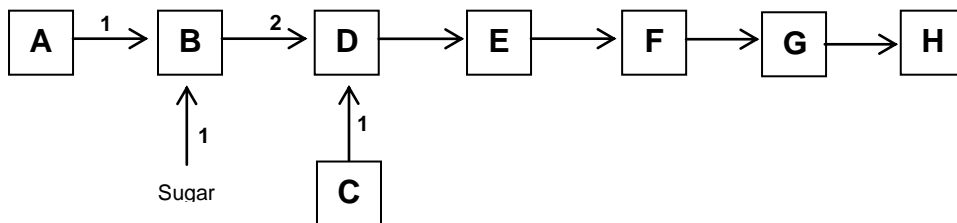
Show (mathematically) that when  $D=P$  the maximum stock level is zero.



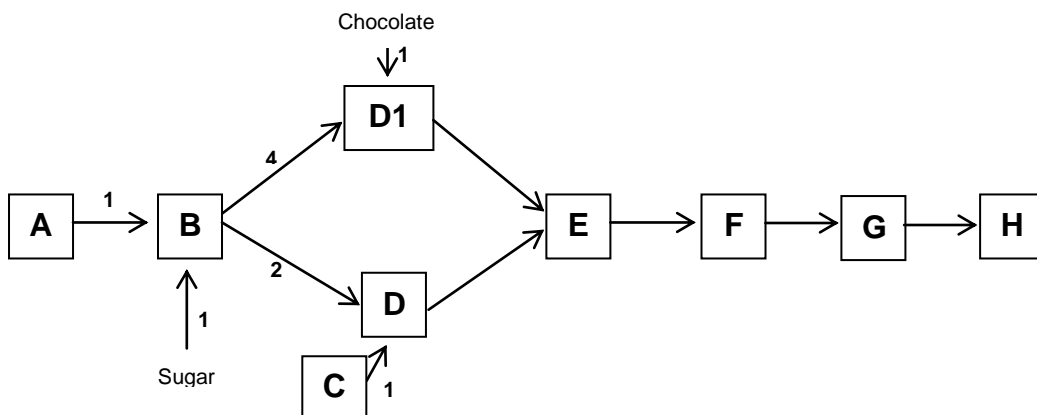
## Group 2 (35 points)

The food company 'Mary Flat Cookies' produces homemade cookies. Given the enormous success of its products, last year the company had to implement a semi-industrial production process that includes the following equipment and production phases:

| Equipment | Function             | Capacity per hour                    | Additional Information  |
|-----------|----------------------|--------------------------------------|---|
| A         | Mixer 1              | Kneads the flour with the eggs       | 40 kg   |
| B         | Mixer 2              | Adds the sugar and knead the mixture | 76 kg<br>1 portion of dough :<br>1 portion of sugar               |
| C         | Refrigeration system | Keeps the milk cold                  | 25 kg   |
| D         | Kneader              | Adds milk and knead it               | 100 kg<br>2 portions of dough:<br>1 portion of milk               |
| E         | Molding system       | Places the biscuits in shapes        | 120 kg  |
| F         | 2 ovens              | Bakes the cookies                    | 2 x 7500 cookies  |
| G         | Cooling docks        | Cools the cookies                    | No limit  |
| H         | Pack & Go            | Places the cookies on packages       | 500 packages<br>Each package weighs 250gr and includes 25 cookies |



- What is the capacity of the system in terms of packs of cookies per hour? Which is the machine that limits the system of producing more cookies per hour (bottleneck)? (assume no loss of weight between the various stages of production)
- Which is the slack on machines A, B and D, measured in terms of final product, ie, packages of 'Mary Flat Cookies'?
- The company is considering diversifying its production because it has been losing customers for some chocolate biscuits. The operations manager knows that, it is possible to produce new chocolate chip cookies ('Mary Chocolate Cookies'), adding only one new phase (D1) to current production process. That is, they just need to buy one new mixer to add the chocolate nuggets to the dough instead of milk (4 portions of dough to 1 portion of chocolate). The new production process would be:



How many packs of 'Mary Chocolate Cookies' can the company produce per hour, without adding capacity to the existing equipment (maintaining the current production of 'Mary Flat Cookies')? What is the minimum capacity that the new mixer D1 must have? What the new system's capacity ('Mary Flat Cookies'+ 'Mary Chocolate Cookies')?

### Group 3 (35 points)

Portuguese Electric Vehicles SA (PEV) is launching the El-Lisbon, their new state of the art electric car, with 250 Km autonomy, 130 Km/h maximum speed, at a selling price of 12.720€. To prepare the El-Lisbon manufacturing, PEV hired you as the new Operations Manager and your first assignment is to determine future sales of El-Lisbon.

PEV has already an electric car, model El-Porto, which will stop to be sold when El-Lisbon is launched. Historical sales from El-Porto can be taken into account to calculate future sales of El-Lisbon. El-Porto Sales during last 2 years were:

| Quarter | El-Porto Sales (units) | Forecast ( $\alpha = 0,2$ ) | Error ( $\alpha = 0,2$ ) | Absolute Err. ( $\alpha = 0,2$ ) | Abs. % Error ( $\alpha = 0,2$ ) |
|---------|------------------------|-----------------------------|--------------------------|----------------------------------|---------------------------------|
| 1       | 12                     | 13                          |                          |                                  |                                 |
| 2       | 15                     | 12,8                        | 2,2                      | 2,2                              | 14,7%                           |
| 3       | 18                     | 13,2                        | 4,8                      | 4,8                              | 26,4%                           |
| 4       | 21                     | 14,2                        | 6,8                      | 6,8                              | 32,4%                           |
| 5       | 27                     | 15,6                        | 11,4                     | 11,4                             | 42,4%                           |
| 6       | 27                     | 17,8                        | 9,2                      | 9,2                              | 33,9%                           |
| 7       | 30                     | 19,7                        | 10,3                     | 10,3                             | 34,4%                           |
| 8       | 36                     | 21,7                        | 14,3                     | 14,3                             | 39,6%                           |

- Calculate the forecast of El-Lisbon sales on its first quarter (Quarter 9), considering two different approaches,  $\alpha = 0,2$  (see table above) and  $\alpha = 0,6$ . Please include error, absolute error and absolute % error in your answer for all quarters calculated. Indicate also the mean absolute deviation (MAD) and consequently indicate which  $\alpha$  you consider better for this forecast and why.
- Consider that electric cars sales in Quarter 8 have a trend of 5 units with  $\beta = 0,2$  and consider also the forecast value calculated in a) for Quarter 8 with the smoothing constant  $\alpha = 0,6$ . Please calculate El-Lisbon sales forecast for the first quarter (quarter 9). If you could not calculate the Forecast for Quarter 8, please consider that forecast to be 29.
- Finally you are in the end of Quarter 9 and the actual sales of El-Lisbon on that quarter were 40. Considering data from b), what would be the forecast for the following period (quarter 10)?

### Group 4 (35 points)

“Herdade da Choupana” is a family estate property located in Alentejo, nearby the city of Beja, well known for their high quality and tasteful wines, certified biologically raised animals and cork production and transsformation.

Conjointly to an ongoing business development program, you have been hired as the Operations Manager who will be responsible to deploy an operational efficiency program and asked to focus on the Winery business, paying special attention to the semi-manual bottling process for their top quality artisanal wine “Muros Caiados”.

This process is expected to continuously delivery 500 bottles per week, on average, requiring one cork stopper per bottle, besides several other items, not relevant for now, and they have enough “Muros Caiados”, aging on oak casks, to feed this process for several years.

- After contacting several cork stoppers suppliers and negotiating with them, you have assured the following commercial proposal:

| Order Quantity | Price per item | Ordering Cost per order | Delivery lead time |
|----------------|----------------|-------------------------|--------------------|
| 1-1999         | € 5            | € 20                    | 4 days             |
| 2000-3999      | € 4            | € 30                    | 6 days             |
| 4000 and up    | € 3            | € 40                    | 8 days             |

Assuming 50 week years, 5 working days per week and an annual per unit inventory holding cost of €0,10, determine the optimal order quantity, associated total costs and reorder point for the chosen scenario.

- b) Given the internal ability to produce 2.500 cork stoppers each day, you have been asked to explore this possibility and define the most profitable production scenario (batch size, total annual costs and average time between orders), knowing that the cost of stopping actual cork transformation activities and setting up machinery to produce cork stoppers is € 340 and the production cost per cork stopper is € 3,50.
- c) Based on your previous analysis, what strategy (buying or producing cork stoppers) would you recommend and why?

#### **Group 5 (20 points)**

Mr. Alberto is the manager of a store that sells t-shirts during the Rock in Rio (RiR) Lisbon with the logo of that event. Every time that this event takes place he has to decide on the number of t-shirts to purchase for the event. The cost of acquisition each t-shirt is 2€. After he purchases the t-shirt he has to customize each t-shirt with RiR's logo. The customization process has a cost of 8€ per t-shirt. He sells the t-shirts in RiR at 20€ each and he knows from the past experience that any unsold t-shirt during the event can be sold after that at 7€. Besides that he doesn't have any kind of holding costs. The manager knows that the demand of t-shirts during RiR is normal distributed with an average of 32500 and standard deviation of 6450. (consider the following information  $NORMINV(0,85;32500;6450)=39184$ ;  $NORMINV(0,77;32500;6450)=37265$ ;  $NORMINV(0,65;32500;6450)=34985$ )

- a) How many t-shirts should the manager purchase for the next RiR?
- b) What should be the selling price of t-shirts in RiR if the manager of the store wants a customer service level of 0.85? (assume that all the costs mentioned above are kept)

# Operations Management

## Midterm 1

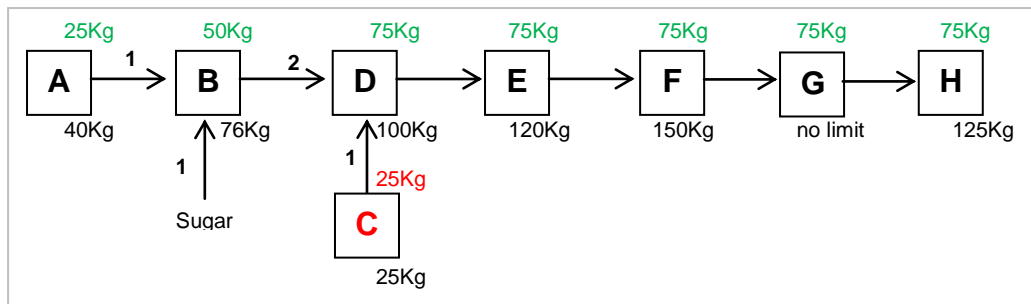
### Solutions

30/3/2011

Duration 2h30m

#### Group 2

- a) What is the capacity of the system in terms of packs of cookies per hour? Which is the machine that limits the system of producing more cookies per hour (bottleneck)? (assume no loss of weight between the various stages of production)

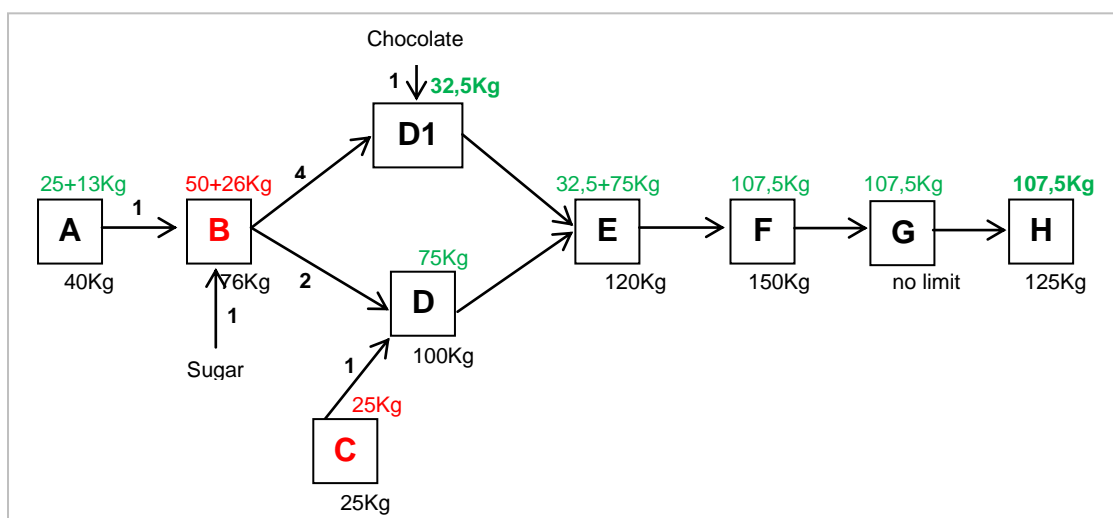


**Answer:** Bottleneck = C | System Capacity = 300 packs / hour

- b) Which is the slack on machines A, B and D, measured in terms of final product, ie, packages of 'Mary Flat Cookies'?

**Answer:** A = 180 packages | B = 156 packages | C = 100 packages

- c) How many packs of 'Mary Chocolate Cookies' can the company produce per hour, without adding capacity to the existing equipment (maintaining the current production of 'Mary Flat Cookies')? What is the minimum capacity that the new mixer D1 must have? What the new system's capacity ('Mary Flat Cookies' + 'Mary Chocolate Cookies')?



**Answer:** 130 packs of 'Mary Chocolate Cookies' | D1 = 32,5 Kg | System capacity = 430 packs of Mary Chocolate Cookies'.

### Group 3 (35 points)

- a) Calculate the forecast of El-Lisbon sales on its first quarter (Quarter 9), considering two different approaches,  $\alpha = 0,2$  (see table above) and  $\alpha = 0,6$ . Please include error, absolute error and absolute % error in your answer for all quarters calculated. Indicate also the mean absolute deviation (MAD) and consequently indicate which  $\alpha$  you consider better for this forecast and why.

$$F1 = 13$$

Option 1:

$$\alpha = 0,2$$

| Quarter | Actual Sales | Forecast | Error | Absolute Err. | Abs. % Error |
|---------|--------------|----------|-------|---------------|--------------|
| 1       | 12           | 13       |       |               |              |
| 2       | 15           | 12,8     | 2,2   | 2,2           | 14,7%        |
| 3       | 18           | 13,2     | 4,8   | 4,8           | 26,4%        |
| 4       | 21           | 14,2     | 6,8   | 6,8           | 32,4%        |
| 5       | 27           | 15,6     | 11,4  | 11,4          | 42,4%        |
| 6       | 27           | 17,8     | 9,2   | 9,2           | 33,9%        |
| 7       | 30           | 19,7     | 10,3  | 10,3          | 34,4%        |
| 8       | 36           | 21,7     | 14,3  | 14,3          | 39,6%        |
| 9       |              | 24,6     |       |               |              |
|         |              |          | Sum   | 59,0          |              |
|         |              |          | Mean  | 8,4           |              |

Formulas to be considered:

$$F_t = F_{t-1} + \alpha (A_{t-1} - F_{t-1})$$

$$FIT_t = F_t + T_t$$

$$F_t = FIT_{t-1} + \alpha (A_{t-1} - FIT_{t-1})$$

$$T_t = T_{t-1} + \beta (F_t - FIT_{t-1})$$

Option 2:

$$\alpha = 0,6$$

| Quarter | Actual Sales | Forecast | Error | Absolute Err. | Abs. % Error |
|---------|--------------|----------|-------|---------------|--------------|
| 1       | 12           | 13       |       |               |              |
| 2       | 15           | 12,4     | 2,6   | 2,6           | 17,3%        |
| 3       | 18           | 14,0     | 4,0   | 4,0           | 22,4%        |
| 4       | 21           | 16,4     | 4,6   | 4,6           | 22,0%        |
| 5       | 27           | 19,2     | 7,8   | 7,8           | 29,1%        |
| 6       | 27           | 23,9     | 3,1   | 3,1           | 11,6%        |
| 7       | 30           | 25,7     | 4,3   | 4,3           | 14,2%        |
| 8       | 36           | 28,3     | 7,7   | 7,7           | 21,4%        |
| 9       |              | 32,9     |       |               |              |
|         |              |          | Sum   | 34,2          |              |
|         |              |          | Mean  | 4,9           |              |

Better Option

|                | MAD |
|----------------|-----|
| $\alpha = 0,2$ | 8,4 |
| $\alpha = 0,6$ | 4,9 |

Has the lower MAD (error)

- b) Consider that electric cars sales in Quarter 8 have a trend of 5 units with  $\beta = 0,2$  and consider also the forecast value calculated in a) for Quarter 8 with the smoothing constant  $\alpha = 0,6$ . Please calculate El-Lisbon sales forecast for the first quarter (quarter 9).

$$F8 = 28,3$$

$$T8 = 5$$

$$\beta = 0,2$$

| Quarter | Actual Sales | Ft   | Tt  | FITt |
|---------|--------------|------|-----|------|
| 8       | 36           |      |     | 33,3 |
| 9       |              | 34,9 | 5,3 | 40,2 |

- c) Finally you are in the end of Quarter 9 and the actual sales of El-Lisbon on that quarter were 40. Considering data from b), what would be the forecast for the following period (quarter 10)?

$$A9 = 40$$

| Quarter | Actual Sales | Ft   | Tt  | FITt |
|---------|--------------|------|-----|------|
| 9       | 40           |      |     |      |
| 10      |              | 40,1 | 5,3 | 45,4 |

**Group 4 (35 points)**

- a) Assuming 50 week years, 5 working days per week and an annual per unit inventory holding cost of €0,10, determine the optimal order quantity, associated total costs and reorder point for the chosen scenario.

$$\begin{aligned}d &= 500 \text{ bottles per week} \\D &= 500 \times 50 = 25.000 \text{ bottles per year} \\C_H &= € 0,10\end{aligned}$$

**Scenario A: Range 1-1999**

$$C_O = € 20 \text{ \& } C_I = € 5$$

$$Q^* = \sqrt{\frac{2 \times D \times C_O}{C_H}} = \sqrt{\frac{2 \times 25.000 \times 20}{0,1}} = 3.162,3$$

Q\* is out of range - not a viable scenario.

**Scenario B: Range 2000-3999**

$$C_O = € 30 \text{ \& } C_I = € 4$$

$$Q^* = \sqrt{\frac{2 \times D \times C_O}{C_H}} = \sqrt{\frac{2 \times 25.000 \times 30}{0,1}} = 3.873,0$$

$$\begin{aligned}TC &= \frac{D}{Q^*} \times C_O + \frac{Q^*}{2} \times C_H + D \times C_I = \\&= \frac{25000}{3873,0} \times 30 + \frac{3873,0}{2} \times 0,1 + 25000 \times 4 = € 100.387,3\end{aligned}$$

**Scenario C: Range 4000 and up**

$$C_O = € 40 \text{ \& } C_I = € 3$$

$$Q^* = \sqrt{\frac{2 \times D \times C_O}{C_H}} = \sqrt{\frac{2 \times 25.000 \times 40}{0,1}} = 4.472,1$$

$$\begin{aligned}TC &= \frac{D}{Q^*} \times C_O + \frac{Q^*}{2} \times C_H + D \times C_I = \\&= \frac{25000}{4472,1} \times 40 + \frac{4472,1}{2} \times 0,1 + 25000 \times 3 = € 75.447,2\end{aligned}$$

Scenario C is less expensive than the others, so EOQ = 4.472,1.

$$ROP = d \times L = \frac{500}{\text{week}} \times \frac{\text{week}}{5 \text{ days}} \times 8 \text{ days} = 800$$

- b) Given the internal ability to produce 2.500 cork stoppers each day, you have been asked to explore this possibility and define the most profitable production scenario (batch size, total annual costs and average time between orders), knowing that the cost of stopping actual cork transformation activities and setting up machinery to produce cork stoppers is € 340 and the production cost per cork stopper is € 3,50.

$$\begin{aligned}P &= 2.500 \text{ cork stoppers per week} \\D &= 500 \times 50 = 25.000 \text{ bottles per year} \\C_S &= € 340 \\C_I &= € 3,50\end{aligned}$$

$$POQ^* = \sqrt{\frac{2 \times D \times C_S}{C_H \times \left(1 - \frac{D}{P}\right)}} = \sqrt{\frac{2 \times 25.000 \times 340}{0,1 \times \left(1 - \frac{500}{2500}\right)}} = 14.577,4$$

$$\begin{aligned}TC &= \frac{D}{Q^*} \times C_S + \frac{Q^*}{2} \times \left(1 - \frac{D}{P}\right) \times C_H + D \times C_I = \\&= \frac{25000}{14577,4} \times 340 + \frac{14577,4}{2} \times \left(1 - \frac{500}{2500}\right) \times 0,1 + 25000 \times 3,5 = € 88.666,2\end{aligned}$$

$$\frac{Q^*}{D} = \frac{14577,4 \text{ cork stoppers}}{500 \text{ cork stoppers/week}} = 29,2 \text{ weeks}$$

- c) Based on your previous analysis, what strategy (buying or producing cork stoppers) would you recommend and why?

The right choice is buying cork stoppers, using EOQ = 4.472,1 as stated on question a), because that's the less expensive choice (and consequently the most profitable one).

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#### Group 5 (20 points)

- a) How many t-shirts should the manager purchase for the next RiR?

$$\begin{aligned} Co &= (2+8) - 7 = 3 \\ Cu &= 20 - (2+8) = 10 \\ CSL &= 10/(3+10) = 0.769 \\ Z_{0.769} &= 0,74 \\ \text{Average Demand} &= 32500 \\ Q &= 32500 + 0.74 * 6450 = \mathbf{37273} \end{aligned}$$

- b) What should be the selling price of t-shirts in RiR if the manager of the store wants a customer service level of 0.85? (assume that all the costs mentioned above are kept)

$$\begin{aligned} 0,85 &= Cu/(Co+Cu) \\ 0.85 &= Cu/(3+Cu) \\ Cu=17 \text{ and } 17 &= P-(2+8) \quad P=27\text{€} \end{aligned}$$