# CHALMERS

**CHALMERS UNIVERSITY OF TECHNOLOGY**
Department of technology management and economics
MSc programme in Supply Chain Management

CLOSED BOOK WRITTEN EXAM IN **OPERATIONS PLANNING AND CONTROL TEK 421**

January 13, 2018

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**Allowed aids:** Pen, eraser, Chalmers-approved calculator and English - Any language dictionary are allowed but no operations, logistics, supply chain management dictionary, etc.

**Problems:** The exam includes eight problems. The last is quantitative. Formulas and tables are found in the back.

**Answers:** Write name and problem number on every sheet. Only answer to one problem on each sheet!! Also remember that your handwriting must be possible to read in order to grade your answers!!

**Grades:** Maximum result is 80 points. 32 points are needed for pass.

**Language:** You must answer in English.

**Examiner:** Patrik Jonsson (1336)

**Questions:** Patrik Jonsson (1336)

**Problem 1 (24 points)**
Identify the correct answer for each of the four questions. Only one answer is correct per question. Write down your answers (letters, e.g. 1.1A, 1.2D, 1.3C…) on an answer sheet. A correct answer gives 1.5 points.

1.1 What is true about operations planning and control?

I. Decisions at one planning level must be made within the limits of decisions taken at the planning level above.
II. Planning methods used must be such that general decisions at one planning level can be transferred to subordinate planning levels.
III. Different planning levels often overlap each other.
IV. The planning horizon and degree of planning detail vary between planning levels.

(A) Only I and IV are correct.
(B) Only I, II and IV are correct
(C) Only I, II and IV are correct
(D) All are correct.

1.2 For a company that produces high value (expensive) products in a fast expanding market, what strategies should be most appropriate?

I. Level strategy
II. Chase strategy
III. Lead strategy (capacity is increased or decreased before demand rises)
IV. Lag strategy (capacity are increased or decreased first when a change in the size of demand is stated).

(A) I and III
(B) I and IV
(C) II and III
(D) II and IV

1.3 Given the following information, calculate the new forecast for Product A for March using exponential smoothing with consideration to trend.

Alpha = 0.3; Beta = 0.5: Actual demand (January) = 700; Actual demand (February) = 750; Seasonal index (January) = 2.1; Seasonal index (February) 2.3: Seasonal index (March) = 2.0; Seasonal index (April) = 1,6; Seasonal index (May) = 1.2; Seasonal index (June) =0.7.

(A) 638
(B) 652
(C) 667
(D) 800

1.4 When generating new forecasts in February, what would the forecast be for May if using a multiplicative trend method? Actual demand (January) = 700; Actual demand February (725); Forecast (March) = 730.

(A) 740
(B) 780
(C) 782
(D) 783

1.5 What is most correct given the following information for a company using exponential smoothing forecasting during the previous year?

| Period | Actual demand | Forecast |
|---|---|---|
| 1 | 250 | 260 |
| 2 | 270 | 258 |
| 3 | 230 | 260 |
| 4 | 305 | 254 |
| 5 | 295 | 264 |
| 6 | 330 | 270 |
| 7 | 275 | 282 |
| 8 | 300 | 281 |
| 9 | 370 | 285 |
| 10 | 400 | 302 |
| 11 | 570 | 321 |
| 12 | 320 | 371 |

(A) The demand error monitoring would have identified a potential demand error during the year.
(B) Lower alpha factor would have improved the forecast accuracy.
(C) The forecast error monitoring tracking signal would have identified a forecast bias.
(D) Higher alpha factor would have improved the forecast accuracy

1.6 What is correct about the master production schedule in an assemble-to-order situation?

(A) There is always a customer order behind a manufacturing order.
(B) Contains unique and defined products.
(C) Contains quantities of product models for delivery
(D) Contains quantities of basic designs to be delivered.

1.7 Given the information below, what would be the correct MPS planned receipts?

Stock on hand: 150, Lot size: 300, Lead time: 1 week, Release time fence: 1 week, Demand time fence: 4 weeks, Planning time fence: 5 weeks. Scheduled receipt: 300 for week 1.

| Period (weeks) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Forecast | 100 | 120 | 150 | 130 | 100 | 100 | 150 | 100 | 150 |
| Actual order | 80 | 140 | 120 | 100 | 50 | | | | |

(A) 300 in weeks 2 and 7
(B) 300 in weeks 4 and 6
(C) 300 in weeks 5 and 7
(D) 300 in weeks 4, 7 and 9

1.8 Given the information above (Problem 1.5), what would be the correct cumulative ATP be in week 5 after receiving the following additional customer orders: 100 in week 5 and 155 in week 6?

(A) -5
(B) 0
(C) 5
(D) Both orders cannot be accepted because of lacking ATP

1.9 What is true about time fences?

I. Rescheduling before the demand time fence is normally not allowed.
II. Rescheduling before the planning time fence is authorized be the responsible planner.
III. Firm planned orders are most common after the planning time fence.

(A) I and II are correct
(B) I and III are correct
(C) II, and III are correct
(D) Only II is correct

1.10 What is not true about overlapping?

(A) It reduces throughput time.
(B) Manufacturing in an operation is divided between several machines.
(C) Manufactured parts are moved to next operation before the entire order quantity is complete.
(D) It results in temporary re-allocation of capacity requirements.

1.11 A firm makes products to stock. Stock replenishment and prioritization of manufacturing orders are based on run-out time planning, using priority figures. Three products (A, B and C) are made to stock. How would they be prioritized given the following information:

| | Product A | Product B | Product C |
|---|---|---|---|
| Manufacturing lead time | 4 | 4 | 3 |
| Demand per week | 150 | 70 | 40 |
| Stock on hand | 310 | 70 | 70 |
| Safety stock | 300 | 70 | 80 |

(A) First A, second B, third C
(B) First B, second A, third C
(C) First B, then C or A
(D) First C, second B, third A

1.12 In what planning environment is pull-based execution and control appropriate?

I. Levelled production
II. Cellular factory layout
III. Process flexibility
IV. Make-to-stock

(A) Only I is correct.
(B) Only I and II are correct
(C) Only I, II and III are correct
(D) All are correct.

1.13 What lot sizing method can generate non-discrete lot sizes with variable time intervals?

(A) Lot-for-lot
(B) EOQ
(C) Silver-Meal
(D) Economic run-out time

1.14 What is not true about pegging?

(A) Lists all the parents in which a component is used, whether there is a demand for the parent or not.
(B) Shows the parents creating the demand for components, the quantities needed, and when.
(C) Uses where-used logic to identify current sources of demand.
(D) May be single-level or full-level.

1.15 Which of the following are always key issues in operations planning and control design?

I. Aligning with corporate strategy
II. Simplifying planning environment
III. Situation-specific selection of planning methods
IV. Investing in advanced software to enable planning

(A) I
(B) I and II
(C) I, II and III
(D) All of them

1.16 What is not true for the master production schedule?

(A) Its planning horizon is the longest lead-time resource
(B) Expresses the anticipated buy schedule
(C) Focuses on product mix
(D) Focuses on a specific level in the bill of the material

**Problem 2 (10 points)**

Explain how S&OP enhances coordination using the coordination mechanisms Strategic alignment, S&OP process, S&OP organization, Tools and data, Culture and leadership, and Performance management.

**Problem 3 (8 points)**

Big Data is often described with four V:s, Volume, velocity, veracity and variety. How do these characteristics affect the use of the data for example in supply chain management?

**Problem 4 (7 points)**

Three different methods for calculating capacity requirements have been presented:

a) One of these methods is using *overall factors*. Why may this method cause inaccurate capacity requirements when there are product mix changes and the various products require a different number of hours to be manufactured?

b) What are the main characteristics of *bill of capacities* as a method to calculate capacity requirements?

c) Why is it necessary to run material requirements planning if you want to use the method *capacity requirements planning*?

**Problem 5 (7 points)**

*Material requirements planning*, *run-out time planning,* and the *re-order point* method are three commonly used material planning methods. How can the respective method support the following planning issues?

a) Material planning when seasonal demand

b) Material planning in a distribution network of linked DCs

c) Sharing requirements information in supply chain

**Problem 6 (7 p)**

Available capacity is one issue that can be of central importance when orders are release to the shop floor. In the course, the order release methods of *order release from planned start times*, *regulated order release*, and *input/output control* have been described.

a) Please explain if and how each of these methods deals with capacity requirements in relation to available capacity.

b) Relating to your answer in a), please describe some typical characteristics of environments where each of the methods is best applied.

**Problem 7 (8 p)**

a) Short setup times are often seen as a prerequisite for an efficient pull system. Why is this?

b) Compared to a kanban system, a CONWIP system is better equipped for handling mix changes over time. Please explain why.

c) In a two-card kanban system, a kanban board can be used. What is a kanban board and how is it used?

**Problem 8 (9 points)**

Pete & Co uses economic order quantities when replenishing its stock of spare parts. Due to high set-up times the ordering cost for one of the manufactured items is €150. The carrying cost per piece and year is €30. The average demand per week is 2 pcs, the standard deviation for the variation in demand is 6 pcs per week and the lead time is 4 weeks. The company uses a re-order point system to control the inventory for the item and applies a fill rate service of 97 % when calculating the safety stock. The year is assumed to have 50 weeks of demand.

a) By using a new machine to manufacture the item the company has managed to reduce the set-up time. The ordering cost is now €20. How much will the total inventory be reduced after this change?

b) How much will the total inventory be reduced if the company instead had used a cycle service of 97 %?

c) A third potential method for calculating safety stocks is to set the safety stock as an estimated percentage of the demand during the lead time. What are the major advantages and/or disadvantages with the respective method (fill rate service, cycle service, percentage of demand during lead time)?

# Formulas and tables

## Forecasting

### Exponential smoothing forecast

$$BF(t+1) = \alpha \cdot D(t) + (1-\alpha) \cdot (BF(t) + T(t))$$
$$T(t+1) = \beta \cdot (BF(t+1) - BF(t)) + (1-\beta) \cdot T(t)$$
$$F(t+n) = BF(t+1) + T(t+1) \cdot n$$

$\alpha = \dfrac{2}{n+1}$

where
BF(t+1) = basic forecast for period 1 without considering trends
BF(t) = basic forecast for current period t without considering trends
T(t) = trend for current period t
T(t+1) = trend from period 1
F(t) = forecast demand for current period t
α = Exponential smoothing constant (forecast)
β = Exponential smoothing constant (trend)
n = Number of future periods covered by the forecast

### Mean error and MAD

$$ME = \frac{\sum(D-F)}{n}$$
$$ME(t) = \alpha \cdot (F(t) - D(t)) + (1-\alpha) \cdot ME(t-1)$$
$$MAD = \frac{\sum\left|D-F\right|}{n}$$
$$MAD(t) = \alpha \cdot \left|F(t) - D(t)\right| + (1-\alpha) \cdot MAD(t-1)$$

where:
ME = Mean error
MAD = Mean absolute deviation
D = Demand
F = Forecast
n = Number of periods

ME(t) = ME in period t
MAD(t) = MAD in period t
α = exponential smoothing constant

# Inventory control

## Standard deviation of demand during lead time

$$\sigma_{DDLT} = \text{standard deviation of demand during lead time} = \sqrt{LT \cdot \sigma_D^2 + \sigma_{LT}^2 \cdot D^2}$$

where LT = average lead time in periods from order to delivery (order cycle)
D = average demand per period
$\sigma_D$ = standard deviation of demand per period
$\sigma_{LT}$ = standard deviation of lead time

## Service level

Service level cycle service in % = $\left(1 - \frac{number\ of\ inventory\ cycles\ with\ shortage}{total\ number\ of\ inventory\ cycles}\right) \cdot 100$

Service level demand fill rate in % = $\left(1 - \frac{demand\ not\ directly\ fulfilled\ from\ inventory}{total\ demand}\right) \cdot 100$

Demand fill rate $= 1 - \frac{\frac{D}{Q} \cdot \sigma_{DDLT} \cdot E(z)}{D} = 1 - \frac{\sigma_{DDLT} \cdot E(z)}{Q}$

where D = demand per year
$\sigma_{DDLT}$ = standard deviation of demand during lead time
Q = average order quantity
E(z) = service loss function

## Shortage costs

When assuming that a stock-out results in lost sales:

$$\Phi(\mathrm{k}) = \frac{SC}{SC + IC \cdot \frac{\mathrm{Q}}{\mathrm{D}}}$$

where $\Phi$(k) = probability that stock-out does not occur during an inventory cycle.
k = service factor
Q = order quantity
IC = inventory carrying cost per unit and time period
SC = shortage cost per stock-out occasion
D = demand per time period

If a stock-out results in a rest (remainder) order and delivery on a later occasion, i.e. the stock-out does not lead to lost sales, the following formula should be used:

$$\Phi(\mathrm{k}) = 1 - \frac{IC \cdot \mathrm{Q}}{\mathrm{D} \cdot SC}$$

## Safety stock determination

$$SS = \mathrm{k} \cdot \sigma$$

where SS = safety stock
k = safety factor
$\sigma$ = standard deviation of demand during lead time

## Kanban

n = $\frac{D \cdot L \cdot (1 + \alpha)}{a}$

where:
D = Demand per time unit
L = Lead time
a = Number of pcs of items in the pallet

## Periodic ordering system

$$T = D \cdot (R + L) + SS$$

$$Q = T - S$$

where Q = order quantity
T = order-up-to level
D = demand per period
R = reordering interval
L = lead time
SS = safety stock
S = stock on hand

## Lot sizing

$$EOQ = \sqrt{\frac{2 \cdot D \cdot S}{I \cdot C}}$$

where:

EOQ = Economic order quantity
D = Demand per period (units per period)
S = Ordering cost per occasion
I = Inventory interest rate (% per time period)
C = Goods value per unit

# Tables of distributions
## Poisson distribution:

| *Average demand during lead time* | *80 %* | *85 %* | *90 %* | *95 %* | *97 %* | *98 %* | *99 %* |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 2 | 2 | 2 | 3 |
| 2 | 1 | 1 | 2 | 2 | 3 | 3 | 4 |
| 3 | 1 | 2 | 2 | 3 | 4 | 4 | 5 |
| 4 | 2 | 2 | 3 | 3 | 4 | 5 | 5 |
| 5 | 2 | 2 | 3 | 4 | 5 | 5 | 6 |
| 6 | 2 | 2 | 3 | 4 | 5 | 5 | 6 |
| 7 | 2 | 3 | 3 | 5 | 5 | 6 | 7 |
| 8 | 2 | 3 | 4 | 5 | 6 | 6 | 7 |
| 9 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 10 | 3 | 3 | 4 | 5 | 6 | 7 | 8 |

Note: Service levels and corresponding Poisson distribution.

***Normal distribution:***

| Safety factor | Service level % | Safety factor | Service level % | Safety factor | Service level % | Safety factor | Service Level % |
|---|---|---|---|---|---|---|---|
| 0.00 | 50.0 | 0.72 | 76.4 | 1.44 | 92.5 | 2.16 | 98.5 |
| 0.02 | 50.8 | 0.74 | 77.0 | 1.46 | 92.8 | 2.18 | 98.5 |
| 0.04 | 51.6 | 0.76 | 77.6 | 1.48 | 93.1 | 2.20 | 98.6 |
| 0.06 | 52.4 | 0.78 | 78.2 | 1.50 | 93.3 | 2.22 | 98.7 |
| 0.08 | 53.2 | 0.80 | 78.8 | 1.52 | 93.6 | 2.24 | 98.7 |
| 0.10 | 54.0 | 0.82 | 79.4 | 1.54 | 93.8 | 2.26 | 98.8 |
| 0.12 | 54.8 | 0.84 | 80.0 | 1.56 | 94.1 | 2.28 | 98.9 |
| 0.14 | 55.6 | 0.86 | 80.5 | 1.58 | 94.3 | 2.30 | 98.9 |
| 0.16 | 56.4 | 0.88 | 81.0 | 1.60 | 94.5 | 2.32 | 99.0 |
| 0.18 | 57.1 | 0.90 | 81.6 | 1.62 | 94.7 | 2.34 | 99.0 |
| 0.20 | 57.9 | 0.92 | 82.1 | 1.64 | 94.9 | 2.36 | 99.1 |
| 0.22 | 58.7 | 0.94 | 82.6 | 1.66 | 95.2 | 2.38 | 99.1 |
| 0.24 | 59.5 | 0.96 | 83.1 | 1.68 | 95.4 | 2.40 | 99.2 |
| 0.26 | 60.3 | 0.98 | 83.6 | 1.70 | 95.5 | 2.42 | 99.2 |
| 0.28 | 61.0 | 1.00 | 84.1 | 1.72 | 95.7 | 2.44 | 99.3 |
| 0.30 | 61.8 | 1.02 | 84.6 | 1.74 | 95.9 | 2.46 | 99.3 |
| 0.32 | 62.6 | 1.04 | 85.1 | 1.76 | 96.1 | 2.48 | 99.3 |
| 0.34 | 63.3 | 1.06 | 85.5 | 1.78 | 96.2 | 2.50 | 99.4 |
| 0.36 | 64.1 | 1.08 | 86.0 | 1.80 | 96.4 | 2.52 | 99.4 |
| 0.38 | 64.8 | 1.10 | 86.4 | 1.82 | 96.6 | 2.54 | 99.4 |
| 0.40 | 65.5 | 1.12 | 86.9 | 1.84 | 96.7 | 2.56 | 99.5 |
| 0.42 | 66.3 | 1.14 | 87.3 | 1.86 | 96.9 | 2.58 | 99.5 |
| 0.44 | 67.0 | 1.16 | 87.7 | 1.88 | 97.0 | 2.60 | 99.5 |
| 0.46 | 67.7 | 1.18 | 88.1 | 1.90 | 97.1 | 2.62 | 99.6 |
| 0.48 | 68.4 | 1.20 | 88.5 | 1.92 | 97.3 | 2.64 | 99.6 |
| 0.50 | 69.1 | 1.22 | 88.9 | 1.94 | 97.4 | 2.66 | 99.6 |
| 0.52 | 69.8 | 1.24 | 89.3 | 1.96 | 97.5 | 2.68 | 99.6 |
| 0.54 | 70.5 | 1.26 | 89.6 | 1.98 | 97.6 | 2.70 | 99.7 |
| 0.56 | 71.2 | 1.28 | 90.0 | 2.00 | 97.7 | 2.72 | 99.7 |
| 0.58 | 71.9 | 1.30 | 90.3 | 2.02 | 97.8 | 2.74 | 99.7 |
| 0.60 | 72.6 | 1.32 | 90.7 | 2.04 | 97.9 | 2.76 | 99.7 |
| 0.62 | 73.2 | 1.34 | 91.0 | 2.06 | 98.0 | 2.78 | 99.7 |
| 0.64 | 73.9 | 1.36 | 91.3 | 2.08 | 98.1 | 2.80 | 99.7 |
| 0.66 | 74.5 | 1.38 | 91.6 | 2.10 | 98.2 | 2.82 | 99.8 |
| 0.68 | 75.2 | 1.40 | 91.9 | 2.12 | 98.3 | 2.84 | 99.8 |
| 0.70 | 75.8 | 1.42 | 92.2 | 2.14 | 98.4 | 2.86 | 99.8 |

## *Service loss function E(z):*

| Safety factor | Service function | Safety factor | Service function | Safety factor | Service function | Safety factor | Service function |
|---|---|---|---|---|---|---|---|
| 0.00 | 0.3989 | 0.72 | 0.1381 | 1.44 | 0.0336 | 2.16 | 0.0055 |
| 0.02 | 0.3890 | 0.74 | 0.1334 | 1.46 | 0.0321 | 2.18 | 0.0052 |
| 0.04 | 0.3793 | 0.76 | 0.1289 | 1.48 | 0.0307 | 2.20 | 0.0049 |
| 0.06 | 0.3699 | 0.78 | 0.1245 | 1.50 | 0.0293 | 2.22 | 0.0046 |
| 0.08 | 0.3602 | 0.80 | 0.1202 | 1.52 | 0.0280 | 2.24 | 0.0044 |
| 0.10 | 0.3509 | 0.82 | 0.1160 | 1.54 | 0.0267 | 2.26 | 0.0041 |
| 0.12 | 0.3418 | 0.84 | 0.1120 | 1.56 | 0.0255 | 2.28 | 0.0039 |
| 0.14 | 0.3328 | 0.86 | 0.1080 | 1.58 | 0.0244 | 2.30 | 0.0037 |
| 0.16 | 0.3240 | 0.88 | 0.1042 | 1.60 | 0.0232 | 2.32 | 0.0035 |
| 0.18 | 0.3154 | 0.90 | 0.1004 | 1.62 | 0.0222 | 2.34 | 0.0033 |
| 0.20 | 0.3069 | 0.92 | 0.0968 | 1.64 | 0.0211 | 2.36 | 0.0031 |
| 0.22 | 0.2986 | 0.94 | 0.0933 | 1.66 | 0.0201 | 2.38 | 0.0029 |
| 0.24 | 0.2904 | 0.96 | 0.0899 | 1.68 | 0.0192 | 2.40 | 0.0027 |
| 0.26 | 0.2824 | 0.98 | 0.0865 | 1.70 | 0.0183 | 2.42 | 0.0026 |
| 0.28 | 0.2745 | 1.00 | 0.0833 | 1.72 | 0.0174 | 2.44 | 0.0024 |
| 0.30 | 0.2668 | 1.02 | 0.0802 | 1.74 | 0.0166 | 2.46 | 0.0023 |
| 0.32 | 0.2592 | 1.04 | 0.0772 | 1.76 | 0.0158 | 2.48 | 0.0021 |
| 0.34 | 0.2518 | 1.06 | 0.0742 | 1.78 | 0.0150 | 2.50 | 0.0020 |
| 0.36 | 0.2445 | 1.08 | 0.0714 | 1.80 | 0.0143 | 2.52 | 0.0019 |
| 0.38 | 0.2374 | 1.10 | 0.0686 | 1.82 | 0.0136 | 2.54 | 0.0018 |
| 0.40 | 0.2304 | 1.12 | 0.0660 | 1.84 | 0.0129 | 2.56 | 0.0017 |
| 0.42 | 0.2236 | 1.14 | 0.0634 | 1.86 | 0.0123 | 2.58 | 0.0016 |
| 0.44 | 0.2169 | 1.16 | 0.0609 | 1.88 | 0.0116 | 2.60 | 0.0015 |
| 0.46 | 0.2104 | 1.18 | 0.0584 | 1.90 | 0.0111 | 2.62 | 0.0014 |
| 0.48 | 0.2040 | 1.20 | 0.0561 | 1.92 | 0.0105 | 2.64 | 0.0013 |
| 0.50 | 0.1978 | 1.22 | 0.0538 | 1.94 | 0.0100 | 2.66 | 0.0012 |
| 0.52 | 0.1917 | 1.24 | 0.0517 | 1.96 | 0.0094 | 2.68 | 0.0011 |
| 0.54 | 0.1857 | 1.26 | 0.0495 | 1.98 | 0.0090 | 2.70 | 0.0011 |
| 0.56 | 0.1799 | 1.28 | 0.0475 | 2.00 | 0.0085 | 2.72 | 0.0010 |
| 0.58 | 0.1742 | 1.30 | 0.0455 | 2.02 | 0.0080 | 2.74 | 0.0009 |
| 0.60 | 0.1687 | 1.32 | 0.0437 | 2.04 | 0.0076 | 2.76 | 0.0009 |
| 0.62 | 0.1633 | 1.34 | 0.0418 | 2.06 | 0.0072 | 2.78 | 0.0008 |
| 0.64 | 0.1580 | 1.36 | 0.0400 | 2.08 | 0.0068 | 2.80 | 0.0008 |
| 0.66 | 0.1528 | 1.38 | 0.0383 | 2.10 | 0.0065 | 2.82 | 0.0007 |
| 0.68 | 0.1478 | 1.40 | 0.0367 | 2.12 | 0.0061 | 2.84 | 0.0007 |
| 0.70 | 0.1429 | 1.42 | 0.0351 | 2.14 | 0.0058 | 2.86 | 0.0006 |