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 420**

January 16, 2016; morning; room: H

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 ten problems. The last are 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 85 points. 36 points are needed for pass.

Language: You must answer in English.

Examiner: Patrik Jonsson (1336)

Problem 1 (14 points)

A manufacturing company is reviewing its production strategy and forecasting approach for one of its main product families. Today the company use a levelled production strategy for production planning and a moving average approach (number of periods, n=5) for forecasting the demand for the product family. However, rapid and unstable market growth during the previous year has made the company interested in changing the production planning approach to a chase strategy and to introduce an exponential smoothing approach with consideration to trends for forecasting the product family demand. A time series of demand data from the previous year and information about the company's production system are shown in tables 1 to 3.

Table 1 – Demand data and forecast from the previous year

Month	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Demand	5400	6700	6600	7600	9300	9500	10800	9600	12400	14300	12900	14900
Moving average forecast (n=5)	-	-	-	-	-	7120	7940	8760	9360	10320	11320	12000

Table 2 – Production information

Type	**Amount**
Employees	12 full time workers
Production rate	5 units per worker and hour
Initial inventory	12 000 units
Safety stock	0 units

Table 3 – Cost information

Type	**Cost**
Regular time	€200 per unit
Overtime	€400 per unit
Inventory	€20 per unit and month
Backorder	€800 per unit and month

a) Design a forecasting approach based on exponential smoothing with trend correction and provide the company with a recommendation on whether to change forecasting approach, based on a MAPE forecast error comparison. Your answer should contain:

- *Motivations behind the recommended parameter values for the smoothing factors, based on a qualitative analysis of the time series data from the previous year.*
- *A demonstration of the accuracy of the forecast design by a MAPE forecast-error presentation for months 8-12, including a comparison with the company's previous Moving Average approach (provided in table 1) for months 8-12.*
- *A presentation of what the designed forecast approach predicts the demand for months 1-3 the next year to be.*

b) As decision basis when evaluating its change of production strategy, the company has requested a cost comparison between its current levelled production strategy and a chase strategy based on the demand data from the previous year. Provide the company with the cost comparison and state whether you recommend the company to change strategy or not. Assume no closing inventory at the end of the year and all months having 20 full time working days with 8 working hours per day.

Problem 2 (12 points)

End product X is manufactured from 1 part Y and 2 parts Z and has demand and cost data according to tables 1 and 2.

Table 1. Demand data for product X for the next 8 weeks.

Week	1	2	3	4	5	6	7	8
Forecast	120	130	125	115	130	150	120	125
Customer orders	115	135	117	105	95	83	54	39

Table 2. Cost data for product X.

Cost parameter	Value
Ordering cost [€]	100
Inventory carrying cost [€]	1.27

Ingoing inventory in week 1 for product X is 200 units and there is a scheduled receipt of 100 units in week 2. The planning system uses a demand time fence of 2 weeks, a planning time fence of 5 weeks and a forecast time fence of 6 weeks. There is also a safety stock of 50 units for product X.

a) Determine the fixed lot size which minimizes total cost for product X and plan the required MPS-deliveries for the next 8 weeks based on this lot size. Also include available to promise in the MPS-record.

b) Four (4) customer orders are received at the marketing department. Decide which of the orders that can be accepted by treating the orders in the same sequence as they arrive and accounting for accepted orders when evaluating later orders. Customer orders cannot be split nor can backlog (i.e. delivery later than the order date) be used. Motivate your answers briefly.

1. A new customer order of 40 in week 2
2. A new customer order of 85 in week 3
3. A new customer order of 80 in week 5
4. A new customer order of 200 in week 7

c) Table 3 shows the work centers required to manufacture parts Y (table 3a) and Z (table 3b).

Table 3a. Work centers used in manufacture of part Y.

Part Y		
Work center	**Setup time**	**Runtime/unit**
WC01 (Cutting)	0.5 h	5 min
WC02 (Lathing)	1.5 h	14 min
WC03 (Painting)	1.0 h	28 min

Table 3b. Work centers used in manufacture of part Z.

Part Z		
Work center	**Setup time**	**Runtime/unit**
WC02 (Lathing)	1.2 h	7 min
WC04 (Drilling)	0.4 h	11 min
WC03 (Painting)	1.0 h	28 min

The work center "WC02 – Lathing" has 3 lathing machines available. The company needs one of these lathes for 20 hours per week for manufacture of other products. Each lathing machine can only process one unit of either part Y or Z at a time. Every MPS of part Y and Z needs to be completed within one week and needs to be available the week before the manufacture of product X starts. The system allows MPS-batches to be split into smaller batches to facilitate efficient planning, but each batch then requires a setup. All work centers operates on 8 hour shifts, 5 working days per week and only run during working hours.

Are the three lathes in WC02 enough to meet to meet the capacity requirements derived from the MPS in task a)? You should motivate your answer with a capacity requirements calculation for work center WC02.

Problem 3 (9 points)

A company produces end product A from components B, C and D. The bill of material for product A is shown in figure 1 and information about the material flows for the items A, B, C and D are shown in table 1.

Table 1. Material flow information for items A, B, C and D.

Item	Inventory on hand	Scheduled receipts	Lot size	Safety stock	Lead time
A	300	None	170	?	1
B	250	None	50	75	2
C	500	500 in week 2 and 4	250	80	1
D	250	200 week 1 and 700 week 5	200	110	1

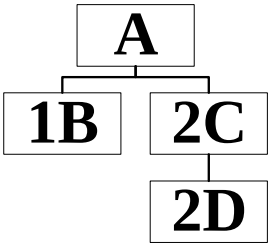

Figure 1. The product structure for product A.

Product A has a weekly forecast of 100 units for the next 8 weeks. Components C and D are used in the manufacture of other products and have weekly demands of 120 products in addition to being part of product A. Product A is an expensive item and has a service level of 95%, a standard deviation of demand of 20 units per week and a standard deviation of lead time of 0.9 weeks. The fixed lot size used for product A has been determined from Wilson's formula (Economic Order Quantity).

a) What is the required safety stock level for product A for the 8 week period, if the service level of 95% is based on the proportion of demand that can be delivered directly from stock (fill rate service)? Demand and lead time may be assumed to be normally distributed.

b) If there is a production capacity constraint of 600 units per week for item D, can the company meet the material requirements for item D over the next 8 weeks? Motivate your answer with an MRP-record for item D. Only integer multiples of the fixed lot sizes can be ordered.

Problem 4 (10 points)

Sales and operations planning (S&OP) and master production scheduling (MPS) are two operations planning and control processes. Some companies focus more on one of these processes, some combine the processes and some only have one of the processes.

a) Explain important similarities and differences between the objectives of the processes.
b) Explain important similarities and differences between the content of the processes.
c) What could be relevant arguments for a company to separate the processes?
d) What could be relevant arguments for a company to combine the two processes?

Problem 5 (12 points)

The following are methods for determining safety stocks: (1) Percentage of leadtime demand, (2) Demand fill rate service, (3) Cycle service (based on Poisson distribution), (4) Cost optimization.

(a) Define the respective method (NB. You don't need to present formulas for how the methods are calculated)
(b) Explain when the respective method would be a feasible method to use.

Problem 6 (6 points)

(a) Why may material requirements planning be a more suitable material planning method than a re-order point method in environments with seasonal variation in demand?
(b) How could a re-order point system be used in order to better deal with seasonality?
(c) Which are the two main differences between the material planning methods run-out time planning and re-order point system?

Problem 7 (12 points)

A wholesaling company distributes products through a central warehouse and ten regional warehouses. Some of the regional warehouses are located geographically close to each other because the demand is high in those areas, while other warehouses are geographically far away from all the other. The delivery service is on average good to all markets, but sometimes there is global shortage of some products. The total tied-up capital in the distribution network is very high. It cannot understand why, because they think they have 'followed the book' when designing its inventory management system. Today the company controls the warehouses with re-order point systems, uses EOQ to determine batch sizes, makes detailed forecasts in each market and uses forecast information to calculate safety stocks based on the order fill-rate model to achieve 95% service level for the respective product.

Task: *Identify and suggest how the material planning of products in the warehouses could be changed in order to improve the performance. List five principally different changes. Describe what the respective change means and how it may affect the material planning performances.*

They do not want to change distribution structure but will keep all warehouses, and also in the future distribute all products through the central warehouse and one regional warehouse. They do not want to change transport set-up but keep the same agreements and transport frequencies. So, your task is to only look at the material planning.

Problem 8 (10 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. 1b, 2d, 3c…) on the answer sheet.

1. The sales forecast should be at a detailed level in which of the following:

(a) Across the entire planning horizon
(b) Up to the planning time fence
(c) From the planning time fence out to the end of the planning horizon
(d) Within the demand time fence

2. The production plan (in the S&OP process) and the master production schedule should:

(a) a. Be expressed in the same unit of measure
(b) b. Be approximately the same level of volume
(c) c. Be in the same level of granularity
(d) d. Extend over the same planning horizon

3. During the S&OP process, performing a financial evaluation of alternative strategies includes which of the following?

I. The number of and productivity of the workers
II. Cost of changing work levels
III. Inventory costs
IV. The priority sequence of the load

(a) II and III
(b) III only
(c) I, II, and III
(d) I, II, III, and IV

4. A time fence policy does which of the following?

(a) Controls the amount of change that can occur during predefined areas of the planning horizon
(b) Controls supply planning information for production
(c) Avoids excess inventory through a dynamic process
(d) Monitors changes in supply and demand conditions

5. Which of the following are data required for the development of a realistic MPS?
I. new product introduction schedule
II. sales forecasts
III. shipment history
IV. workforce constraints

(a) I, II, and III only
(b) I, II, and IV only
(c) I, III, and IV only
(d) I, II, III, and IV

6. How will the amount of safety stock change if changing from re-order point system to periodic ordering system, if keeping the same order-line fill rate service?

(a) The safety stock will not change
(b) The safety stock will increase
(c) The safety stock will decrease
(d) We cannot tell if and how the safety stock will change. More information is needed.

7. What situation is most appropriate for capacity planning using capacity bills?

(a) When lead times are twice the length of a planning period.
(b) For master production scheduling of order-based products.
(c) When long set-up times and varying order quantities.
(d) When consideration to stock on hand is required.

8. What is true about demand error monitoring?

(a) It is made to prevent incorrect or extremely deviating demand values from influencing forecast calculations.
(b) It is made to automatically detect and signal when forecasts are systematically too high or too low.
(c) MAPE is a commonly used measure in the demand error monitoring process.
(d) It is a forecasting method aiming at minimizing the forecast error.

9. What is true about the final assembly schedule?

(a) The FAS always concern unique and defined products.
(b) FAS always refers to released manufacturing orders for specific product variants.
(c) FAS is always tied to customer orders.
(d) FAS and MPS can have the same planning horizon.

10. What could be a benefit from using pyramid forecasting?

(a) Forecast makers are being better tied to their forecasts.
(b) Business cycle considerations are being better considered in the forecasting.
(c) Short term forecast accuracy is improved.
(d) Forecast accuracy is improved for new products.

Formulas and tables

Forecasting

Exponential smoothing forecast

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

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

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

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

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
σ_D = standard deviation of demand per period
σ_{LT} = standard deviation of lead time

Service level

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

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

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

where D = demand per year
σ_{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:

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

where Φ(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:

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

Safety stock determination

$$SS = k \cdot \sigma$$

where SS = safety stock
k = safety factor
σ = 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