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**

Exam January 17, 2015

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 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 100 points. 40 points are needed for pass.

Language: You must answer in English.

Examiner: Patrik Jonsson

Questions: Patrik Fager (031 7721354) and
Linea Kjellsdotter Ivert (031 772 1331)

Problem 1 (18 points)
The Operations planning and control (OPC) model could be described as a frame of references when it comes to planning of material flows and production in manufacturing companies.
a) Explain the purpose of operations planning and control in manufacturing companies.
b) Explain why we need to have both a material and a capacity perspective.
c) Discuss the relationship between the OPC model and the levels of control (strategic, tactical, operations) in a manufacturing company.
d) Explain the aim of time fences in OPC and describe how time fences are used on different planning levels in the OPC model.

Problem 2 (16 points)
Different types of forecasting methods are available. Exponential smoothing, regression analysis, sales management, and grassroots approach are four types. This problem is about how these four types of methods could be used, combined, or not be used by a manufacturer of wood furniture.

The manufacturer makes a product in large volumes to a larger retailer. This product is MTS and distributed in weekly batches to the retailer. It also sells a limited amount of products directly to consumers through its web shop. A mix of MTS and MTO strategy is used for the web shop assortment (MTS in periods of low order volumes from the retailer – otherwise MTO). About 50% of the sales volumes are to the retailer. The same manufacturing resources (machines and people) are used for all products. All people are employed and machines are quite expensive – therefore the manufacturer aims at always producing as close to maximum resource utilization as possible. When low order stock or high inventory stock levels, campaigns are sometimes used to boost the sales of the web shop assortment and keep the high utilization rate and not too high stock levels. The throughput time in manufacturing varies between a couple of weeks to several months. The purchasing lead time also varies between weeks and months. There are long term agreements with a few important and high volume suppliers. Some items are bought from other existing suppliers without agreements, and some items are bought from new suppliers with which it hasn't previously had business. The manufacturer has S&OP and MPS processes and uses an MRP system to plan and control stocked items. It receives delivery schedules with six months horizon from the retailer.

a) Define what forecasting needs (What different planning and control processes and decisions require forecast? What objects and horizons?) you see for the wood manufacturer.
b) Explain how the four forecasting approaches could be used, combined, or not be used by the manufacturer.
NB! Clearly state and motivate any assumption you make regarding the manufacturer, retailer, products, markets, manufacturing, etc.

Problem 3 (16 points)
Cosmetica is a company making and selling cosmetics products to different retailers in Scandinavia. Cosmetica has a manufacturing plant in Sweden where some of the products are made, but it also buys several products from external manufacturers. All manufactured and bought products are stored in a central warehouse located close to the manufacturing site. Cosmetica's distribution network contains the central warehouse and five regional warehouses. Each regional warehouse supplies one market region. No product is distributed directly from the manufacturing plant to a retailer but all products go through the central warehouse and one regional warehouse. The contribution margins are high for most products. There are five regional sales managers who forecast the assortment in his/her region and plan local campaigns. The forecast accuracy on SKU level is considered quite okay, especially on a medium horizon (3 months which equals the average manufacturing and purchasing lead times) and in weekly buckets. But the accuracy is not good when using daily buckets and on time horizons longer than 6 months. They sell quite well, but still, Cosmetica suffers from bad cash flow, high stock levels, and frequent stockouts of some products and obsolences of other products in the regional warehouses.

An ERP system is used to plan warehouse replenishments, but none at Cosmetica understands how the replenishment plans are generated in the system. Therefore, they have started to read textbooks on operations planning and control and have understood that they can choose to control the warehouse stocks with different materials planning methods, and that the way they dimension the safety stocks also is important. From their reading they have identified the following materials planning methods: re-order point method, MRP/time-phased order point, and DRP.

a) Describe strengths and weaknesses of the re-order point method, MRP/time-phased order point method, and DRP method for controlling Cosmetica's distribution network. Suggest what method they should use.
b) How does the safety stock strategy affect Cosmetica's performances? What would be important safety stock issues for Cosmetica to consider in order to improve its performances?

Problem 4 (16 points)
The cutting tool manufacturer Tools AB makes and globally markets metal cutting solutions. The production site in Mölndal consists of a number of work centres arrange according to the routing of most products and includes on average 13 operations steps. Within each work centre there are different types of machines that do a variety of works. The volumes are high and the production variants around 7000. The set up times are between a couple of minutes to 3h and the manufacturing lead times average 21 days. There are a lot of uncertainties on the shop floor in terms of rush orders, rework, unavailability of tools and machine breakdown. There are also many ways to cope with those uncertainties (e.g. orders may be run in parallel machines, it is possible to split an order, operators are flexible and may work in different work centres). The new CEO at Tools AB would like to move from the current priority method supervisor-managed priority

control to priority control by dispatch lists. As the production manager at Tools AB you are asked to help her (the CEO) with the following:

a) Compare supervisor-managed control and priority control by dispatch list (i.e. capacity consideration, links with material planning and dependency on job reporting) and discuss the pros and cons of the respective method.
b) Discuss the challenges in the current planning environment of Tools AB to make good use of priority control by dispatch lists.
c) Suggest some actions in accordance with the identified challenges in order for Tools AB to make good use of priority control by dispatch lists.

Problem 5 (14 points)
A company is reviewing their production strategy and forecasting approach. Today the company uses a levelled production strategy for one of its main products and is considering introducing an exponential smoothing approach for forecasting the product demand. The company is also considering changing their production strategy to a chase strategy due to anticipated increased market shares. Demand data from the previous year and information about the company's production system and costs are shown in tables 1 to 3.

Table 1 – Demand data from the previous year

Month	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
D	6000	6200	6600	6400	6800	7000	7400	7400	7600	7800	8200	8600

Table 2 – Production information

Type	**Amount**
Employees	5 full time workers
Production rate	9 units per worker and hour
Initial inventory	2000 units
Safety stock	0 units

Table 3 – Cost information

Type	**Cost**
Regular time	€120 per unit
Overtime	€200 per unit
Inventory	€30 per unit and month
Backorder	€1000 per unit and month

a) Make a recommendation to the company on which exponential smoothing forecast approach to use for achieving the highest possible forecast accuracy. Your answer should be based on the provided demand data from the previous year and should include:

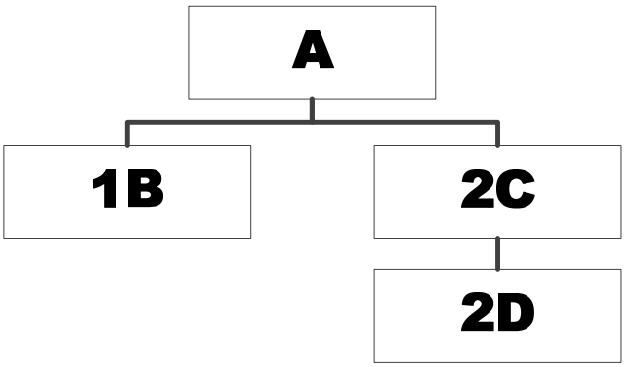
- ✓ An analysis of the data indicating characteristics relevant for your recommendations
- ✓ Motivations of parameter values for the recommended technique.

- ✓ A demonstration of the accuracy of your forecast recommendation by a MAD forecast-error presentation for months 9-12.
- ✓ A sample of what your forecast recommendation predicts the demand for months 1-3 year 2 to be.

b) As decision basis when evaluating their change of production strategy, the company has requested a cost comparison between their 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 clearly 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.

Problem 6 (12 points)

A company produces end product A from components B, C and D. The bill of material for product A and information about the material flows for product A and components B, C and D are shown below.



Item	Inventory on hand	Scheduled receipts	Lot size	Safety stock	Lead time
A	150	None	?	?	1
B	120	30 in week 1	30	40	2
C	170	120 in week 2	60	55	2
D	250	80 in week 2	80	70	1

Product A has a weekly forecast of 40 units and a fixed lot size. Component C is used in the manufacture of other products and has a weekly demand of 20 products in addition to being part of product A. The inventory carrying cost for product A is €30 per product per year and the ordering cost is €65 per order. Product A has a service level of 97% and a standard deviation of demand and lead time of 15 units and 0.5 weeks respectively.

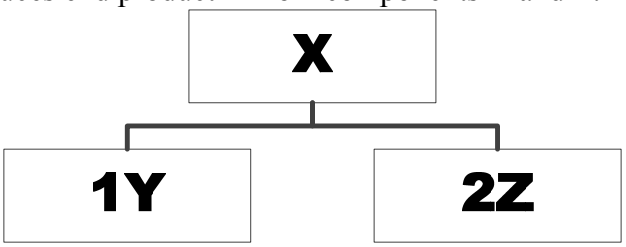
a) Determine the fixed lot size for product A which minimizes the total cost
b) Determine the necessary safety stock for Product A based on cycle service. Assume demand and lead time to be normally distributed.

After an MRP calculation for product A, it is concluded that planned order deliveries of one lot size are needed in weeks 3, 5 and 8.

c) Provide the company with an MRP for item D for the next 8 weeks (including the lot size from a) and the safety stock from b))

Problem 7 (8 points)

A company produces end product X from components Y and Z.



Product X has the following forecast and demand data.

Week	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Forecast	100	110	105	90	100	115	110	105
Customer orders	92	101	83	106	91	81	73	54

The master production schedule has a fixed order quantity of 200. Ingoing inventory in week 1 is 100 units and there are planned MPS deliveries of 200 units in weeks 2, 4, 5 and 7. The demand time fence is 2 weeks and the forecast time fence is six weeks.

a) Provide the company with an MPS-record for end product X, including available to promise.

b) Four (4) customer orders are received at the marketing department. Decide which orders that can be accepted by treating the orders in the same order as they arrive (start with order no. 1 and continue to order no. 2 and so forth). It is not allowed to split customer orders nor use backlog. There is a planning time fence of 5 weeks. Motivate your answers.

1. A new customer order of 20 in week 3
2. A new customer order of 40 in week 5
3. A new customer order of 4 in week 2
4. A new customer order of 80 in week 7

c) In order to produce Parts Y and Z, the following work centres are required.

Part Y		
Work centre	**Setup Time**	**Runtime / unit**
01	0.5 h	1 min
02	1 h	6 min
03	0.8 h	6 min

Part Z		
Work centre	**Setup Time**	**Runtime / unit**
04	1.2 h	5 min
02	1.5 h	2.5 min

How many shifts per day would be required to meet the capacity requirements in work centre 02? Each MPS quantity requires a setup. Assume

8 hours shifts, 5 working days per week and that the work centres only run during working hours. You should motivate your answer with a capacity requirements calculation for work centre 02.

Formulas and tables

Forecasting

Exponential smoothing forecast

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

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

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

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

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

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

where D = demand per year
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:

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

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
σ = standard deviation of demand during lead time

Kanban

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

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