	Examination
Course:	**Production and Logistics Planning**
Date:	**2015-11-03**
Number of hours:	**5 hours**
Group:	**Freestanding course**
Course code:	**KPP227**
Examination code:	**TEN1**
Help Means:	**Ruler, Calculator, Dictionary**
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Good luck!

Please make your calculations on Graph paper.

Max points: 100

Number of points for each task is denoted within parenthesis.

For grade 3 at least 50 is required; grade 4 at least 65; and grade 5 at least 85.

For ECTSgrades: E at least 50p, D at least 60, C at least 70, B at least 80, A at least 90.

1. (6p)

A manager is trying to decide whether to build a small, medium, or large factory. Demand can be low, average, or high, with the estimated probabilities being 0.40, 0.50, and 0.10 respectively.

A small facility is expected to earn $15,000 if demand is low. If demand is average, the small facility is expected to earn $55,000. It can be increased to average size, but due to the expansion costs the earnings will then only be $45,000. If demand is high, the small facility is expected to earn $55,000. If expanded to average size the expansion costs reduce the earnings to $45,000 and if expanded to large size it will earn $88,000.

A medium sized facility is expected to lose an estimated $25,000 if demand is low, and earn $90,000 if demand is average. If demand is high, the medium-sized facility is expected to earn $90,000; it can be expanded to a large size to earn $120,000 instead of $90,000.

If a large facility is built and demand is high, earnings are expected to be $220,000. If demand is average for the large facility, it is expected to earn $120,000; if demand is low, the facility is expected to lose $60,000.

a) Draw the decision tree for this problem.
b) What should management do to achieve the highest expected payoff?

2. (6p)

A company is designing a new assembly station for a product. The assembly station is able to assemble products at an average rate of 9 products per hour according to a negative exponential distribution. Component kits for assembly arrive at an average rate of 6 units per hour, following a Poisson distribution. They are served according to FIFO and each component kit requires 2.5 m^2 in storage space. A product is in this stage of the production process has a value of 2500 €.

a) How much floor space is required for storing component kits in queue for assembly?
b) What's the average value of products within the assembly system?
c) What is the probability of having more than 7 units in the system?

3. (6p)

A company wants to design a new assembly line for their latest products. The company wants to produce at least 270 units per day and they expect to operate the production line 450 minutes per day. The assembly requires 14 different tasks and the work element data is shown in the table below.

Work element	Time (seconds)	Immediate Predecessor(s)
A	10	None
B	25	None
C	10	None
D	35	A
E	65	B, C
F	35	A, E
G	30	None
H	20	D, G
I	45	A
J	50	None
K	20	None
L	40	J, K
M	30	A, L
N	70	F, H, I, M

a) Draw a precedence diagram.
b) What cycle time results in the desired output rate?
c) What is the theoretical minimum number of work stations?
d) Using longest work-element rule, balance the assembly line.
e) What is the efficiency of your solution?

4. (7p)

Consider the job times in the table for a three-machine problem. Assume that the jobs are processed in the sequence M1-M2-M3.

Job	M1	M2	M3
A	15	20	32
B	36	24	40
C	32	8	24
D	24	12	28
E	20	16	44

a) Motivate why this can be solved by Johnson's rule.
b) Find the optimum sequence for processing the five jobs below and show it in a Gantt chart for all three machines, indicating the total processing time.

5. (10p)

The BOMs (Bill Of Materials) for products A, B and C are shown in Table 1 below. Data from inventory records are shown in Table 2. The MPS calls for the following products to be produced:

Product A: 100 units to be completed in week 4, and 55 units in week 7. The lead-time for production of product A is one week.

Product B: 125 units to be completed in week 7. The lead-time for production of product B is two weeks.

Product C: 80 units to be completed in week 7. The lead-time for production of product C is three weeks.

Item	Made of: Number x Item
A	2xD, 1xE
B	1xD, 2xE
C	2xD, 2xE
E	2xF

Table 1

Inventory Record Data:

Data category	D	E	F
Lot sizing rule	FOQ = 150	L4L	POQ (P=2)
Lead time	3 weeks	1 week	2 weeks
Safety stock	50	0	40
Scheduled receipts	250 (week 1)	120 (week 2)	None
On-hand inventory	150	0	100

Table 2

Develop the materials requirement plan for the next eight weeks for the production of products A, B, and C. An MRP template is included in the exam for your convenience.

6. (8p)

A manufacturing company has three factories that supply four major warehouses. The capacity of each factory, and the demand of each warehouse, is listed in the table below. Also, the corresponding transportation costs from each factory to each warehouse are indicated in the table. Use the Modified Transportation Method (MODI) to optimize the distribution of goods from the factories to the warehouses.

		Demand			
		85	65	105	95
Capacity	50	4	10	2	6
	125	6	2	14	8
	175	8	12	2	10

7. (6p)

Name, and explain the five steps, used when practically applying Theory of constraints.

8. (8p)

The monthly demand for a certain product manufactured by a company has been as follows:

Month:	May	June	July	August	September	October	November	December
Units:	90	86	99	105	95	101	115	108

a) Use the exponential smoothing method to forecast the number of units for June - January. The initial forecast for May was 85 units; $\alpha = 0.5$.
b) Calculate the absolute percentage error for each month from June through December and the MAD and MAPE of forecast error for that period.

9. (4p)

a) Name four functions of inventory.
b) Name four reasons to keep high levels of inventory.

10. (6p)

As an inventory manager you must decide on the order quantity for an item that has an annual demand of 2000 units. Placing an order cost you €55 each time. Your annual holding cost, expressed as a percentage of average inventory value is 15%. Your supplier has provided the following price schedule:

Order size	Price per unit
1 – 399	€ 3:00
400 – 799	€ 2:80
800 – 1199	€ 2:50
1200 -	€ 1:80

What is the best order policy from a cost perspective, and what is the resulting total cost?

11. (6p)

Answer the two questions below in detail!

a) How do the logistics strategy for a certain product change over the different phases of the product life cycle?
b) How do Pareto's law influence the inventory management?

12. (5p)

The supply manager of a chemical plant must determine the lot size for a particular chemical that has a steady demand of 30 barrels per day. The production rate is 360 barrels per day, annual demand is 20,500 barrels, setup cost is $200, annual holding cost is $0.21 per barrel, and the plant operates 350 days per year. Determine the following:

a) The economic production lot size.
b) The total annual setup and inventory holding cost for this chemical.
c) The time between orders (TBO) or cycle length.
d) The production time per lot.

13. (10p)

A company that produces gearboxes is planning the production for the coming six-month period. Forecast demands over the next six months for a particular gearbox type are as follows:

Month	Forecast	Working days
January	1920	20
February	960	24
March	1350	18
April	1800	26
May	3000	22
June	2100	15

One worker can produce an average of 0.45 gearboxes per day. Currently (in the end of December), there are 160 workers employed in the plant. Ending inventory in December is expected to be 500 units, and the firm whish to have 900 units in inventory at the end of June. The average wages are $3000 per month including benefits. The cost for dismissal of a worker is $5000, and the cost for hiring and training of a new worker is $3000. On hand inventory that is not sold cost $15 for holding. Use both Chase- and Level strategy to solve the aggregate planning and indicate which strategy is the better one.

14. (6p)

Suppose that the normal time for cutting a gear is a function of the number of gear teeth. The normal times (in minutes) for cutting different 8-inch diameter gears are shown in the table below. The next 8-inch diameter gear is to have 32 teeth. Use linear regression to estimate how long the cutting time will be for that gear.

Number of teeth	Cutting time
23	112
17	84
10	53
28	135
14	70

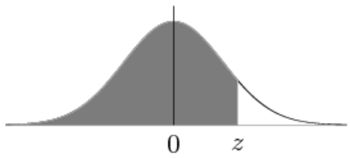
15. (6p)

A company that manufactures brake discs for the automotive industry is considering four different locations, Köping, Eskilstuna, Sala and Västerås for their new factory. Studies have revealed that the fixed costs per year at the sites are $250,000; $100,000; $150,000, and 200,000 respectively. The variable costs are $15 in Köping, $30 in Eskilstuna, $20 in Sala, and $35 in Västerås, per unit.

a) Plot the total-cost lines for these locations on a single graph.
b) In which exact range of production volumes would each alternative be the most economical?
c) If the company expects to produce a volume of 8000 discs per year, which location would provide the lowest cost?

Cumulative Normal Distribution Table

$$\Phi(z) = \int_{-\infty}^{z} \frac{1}{\sqrt{2\pi}} e^{-s^2/2}\, ds$$



z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	.5000	.5040	.5080	.5120	.5160	.5199	.5239	.5279	.5319	.5359
0.1	.5398	.5438	.5478	.5517	.5557	.5596	.5636	.5675	.5714	.5753
0.2	.5793	.5832	.5871	.5910	.5948	.5987	.6026	.6064	.6103	.6141
0.3	.6179	.6217	.6255	.6293	.6331	.6368	.6406	.6443	.6480	.6517
0.4	.6554	.6591	.6628	.6664	.6700	.6736	.6772	.6808	.6844	.6879
0.5	.6915	.6950	.6985	.7019	.7054	.7088	.7123	.7157	.7190	.7224
0.6	.7257	.7291	.7324	.7357	.7389	.7422	.7454	.7486	.7517	.7549
0.7	.7580	.7611	.7642	.7673	.7704	.7734	.7764	.7794	.7823	.7852
0.8	.7881	.7910	.7939	.7967	.7995	.8023	.8051	.8078	.8106	.8133
0.9	.8159	.8186	.8212	.8238	.8264	.8289	.8315	.8340	.8365	.8389
1.0	.8413	.8438	.8461	.8485	.8508	.8531	.8554	.8577	.8599	.8621
1.1	.8643	.8665	.8686	.8708	.8729	.8749	.8770	.8790	.8810	.8830
1.2	.8849	.8869	.8888	.8907	.8925	.8944	.8962	.8980	.8997	.9015
1.3	.9032	.9049	.9066	.9082	.9099	.9115	.9131	.9147	.9162	.9177
1.4	.9192	.9207	.9222	.9236	.9251	.9265	.9279	.9292	.9306	.9319
1.5	.9332	.9345	.9357	.9370	.9382	.9394	.9406	.9418	.9429	.9441
1.6	.9452	.9463	.9474	.9484	.9495	.9505	.9515	.9525	.9535	.9545
1.7	.9554	.9564	.9573	.9582	.9591	.9599	.9608	.9616	.9625	.9633
1.8	.9641	.9649	.9656	.9664	.9671	.9678	.9686	.9693	.9699	.9706
1.9	.9713	.9719	.9726	.9732	.9738	.9744	.9750	.9756	.9761	.9767
2.0	.9772	.9778	.9783	.9788	.9793	.9798	.9803	.9808	.9812	.9817
2.1	.9821	.9826	.9830	.9834	.9838	.9842	.9846	.9850	.9854	.9857
2.2	.9861	.9864	.9868	.9871	.9875	.9878	.9881	.9884	.9887	.9890
2.3	.9893	.9896	.9898	.9901	.9904	.9906	.9909	.9911	.9913	.9916
2.4	.9918	.9920	.9922	.9925	.9927	.9929	.9931	.9932	.9934	.9936
2.5	.9938	.9940	.9941	.9943	.9945	.9946	.9948	.9949	.9951	.9952
2.6	.9953	.9955	.9956	.9957	.9959	.9960	.9961	.9962	.9963	.9964
2.7	.9965	.9966	.9967	.9968	.9969	.9970	.9971	.9972	.9973	.9974
2.8	.9974	.9975	.9976	.9977	.9977	.9978	.9979	.9979	.9980	.9981
2.9	.9981	.9982	.9982	.9983	.9984	.9984	.9985	.9985	.9986	.9986
3.0	.9987	.9987	.9987	.9988	.9988	.9989	.9989	.9989	.9990	.9990
3.1	.9990	.9991	.9991	.9991	.9992	.9992	.9992	.9992	.9993	.9993
3.2	.9993	.9993	.9994	.9994	.9994	.9994	.9994	.9995	.9995	.9995
3.3	.9995	.9995	.9995	.9996	.9996	.9996	.9996	.9996	.9996	.9997
3.4	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9998

Capacity formulas

Capacity

Machine requirements for single products

$$M = \frac{Dp}{N[1-(C/100)]}$$

Machine requirements for multiple products

$$M = \frac{[Dp + (D/Q)s]_{product\ 1} + [Dp + (D/Q)s]_{product\ 2} + \cdots + [Dp + (D/Q)s]_{product\ n}}{N[1 - (C/100)]}$$

M = Number of machines

D = Yearly demand

p = processing time per product

Q = Batch size

s = setup time per batch

N = Total operating time per year

C = Desired capacity cushion (expressed in %)

Break-even analysis

Total cost $$C = F + c \times Q$$

Total revenue $$R = p \times Q$$

Break even quantity $$Q = \frac{F}{(p-c)}$$

C = Total cost

F = Fixed cost

c = variable cost

Q = Quantity of sold products/services

R = Total revenue

p = revenue per sold unit

Forecasting formulas, KPP227

Linear regression:

$$Y = a + bX$$

$$b = \frac{\Sigma XY - n\bar{X}\bar{Y}}{\Sigma x^2 - n\bar{X}^2}$$

$$a = \bar{Y} - b\bar{X}$$

Forecast accuracy (Linear regression):

Correlation coefficient: $$r = \frac{n\sum XY - \sum X \sum Y}{\sqrt{[n\sum X^2 - (\sum X)^2][n\sum Y^2 - (\sum Y)^2]}}$$

Coefficient of determination: $$r^2 = \frac{a\sum Y + b\sum XY - n\bar{Y}^2}{\sum Y^2 - n\bar{Y}^2}$$

Standard error of the estimate: $$\sigma YX = \sqrt{\frac{\sum Y^2 - a\sum Y - b\sum XY}{n-2}}$$

Weighted moving average

$$F_{t+1} = W_1 D_t + W_2 D_{t-1} + \cdots W_n D_{t-n+1}$$

Exponential smoothing

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

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

Exponential smoothing with trend

$$A_t = \alpha D_t + (1-\alpha)(A_{t-1} + T_{t-1})$$

$$T_1 = \beta (A_t - A_{t-1}) + (1-\beta) T_{t-1}$$

$$F_{t+1} = A_t + T_t$$

A_t =exponential smoothed average of the series in period t

T_t =exponential smoothed average of the trend in period t

α = smoothing parameter for average (value 0-1)

β = smoothing parameter for trend (value 0-1)

T_{t+1} = Forecast for period t+1

Forecast errors

Forecast error $$E_t = D_t - F_t$$

Average forecast error $$\bar{E} = \frac{CFE}{n}$$

Mean square error $$MSE = \frac{\sum {E_t}^2}{n}$$

Mean absolute deviation $$MAD = \frac{\sum |E_t|}{n}$$

Standard deviation $$\sigma = \sqrt{\frac{\sum (E_t - \bar{E})^2}{n-1}}$$

Mean absolute percentage error $$MAPE = \frac{\sum [|E_t|(100)]/D_t}{n}$$

Tracking signal $$Tracking\ Signal = \frac{CFE}{MAD}$$

Inventory management

Holding cost

$$Holding\ cost = \frac{Q}{2}(H)$$

Ordering-/setup cost

$$Ordering\ or\ setup\ cost = \frac{D}{Q}(S)$$

Material handling cost

$$C = \frac{Q}{2}(H) + \frac{D}{Q}(S)$$

Economic order quantity

$$EOQ = \sqrt{\frac{2DS}{H}}$$

Time between orders

$$TBO_{EOQ} = \frac{EOQ}{D}$$

Q = Order quantity

H = Holding cost per item

D = Forecasted demand

S = Setup cost per order

Continuous review (Q) system

Inventory position

$$IP = OH + SR - BO$$

IP = Inventory Point

OH = On-hand inventory

SR = Scheduled receipts

BO = Back orders

Re-order point

$$R = \bar{d}L + Safety\ stock$$

$\bar{d}$ = Average demand per time unit

L = constant lead time In time units

Standard deviation of demand during lead time: $\sigma_{dLT} = \sqrt{\sigma_d^2 L} = \sigma_d \sqrt{L}$

Safety stock: $= z\sigma_{dLT}$

Periodic review (P) system

$$T = \bar{d}(P + L) + z\sigma_{(P+L)} = \bar{d}(P + L) + z\sigma_d \sqrt{P + L}$$

T = average demand during the protection interrval + safety stock for protection interval

P = length of time between reviews

Noninstantaneous replenishment

Maximum cycle inventory: $I_{max} = \frac{Q}{p}(p - d) = Q\left(\frac{p-d}{p}\right)$

p = production rate

d = demand rate

Q = lot size

Total annual cost: $C = \frac{I_{max}}{2}(H) + \frac{D}{Q}(S)$

Total annual cost: $C = \frac{Q}{2}\left(\frac{p-d}{p}\right)(H) + \frac{D}{Q}(S)$

Economic production lot size: $ELS = \sqrt{\frac{2DS}{H}}\sqrt{\frac{p}{p-d}}$

I = Inventory
D = annual demand
p = production rate
d = demand rate
Q = lot size
H = holding cost
S = ordering/setup cost

Quantity discounts

Total annual material cost: $C = \frac{Q}{2}(H) + \frac{D}{Q}(S) + PD$

Q = lot size
H = holding cost
D = annual demand
S = ordering/setup cost
P = Price/unit
D = Demand rate

One period decisions

Payoff: $If\ Q \leq S \Rightarrow Payoff = pQ$

$If\ Q > S \Rightarrow Payoff = pD - ld$

p = profit/unit
Q = Purchased quantity
D = actual demand
l = loss/unit
d = number of disposed items

Location formulas, KPP227

Location

Load distance $ld = \sum_i l_i d_i$

Euclidian distance $d_{AB} = \sqrt{(X_A - X_B)^2 + (Y_A - Y_B)^2}$

Rectilinear distance $d_{AB} = |X_A - X_B| + |Y_A - Y_B|$

Center of gravity

$X^* = \frac{\sum l_i X_i}{\sum l_i}$ $Y^* = \frac{\sum l_i Y_i}{\sum l_i}$

Waiting lines formulas, KPP227

Waiting lines

Interarrival times

$$P_n = \frac{(\lambda T)^n}{n!} e^{-\lambda T} \quad \textit{for n = 1,2,...}$$

P_n = Probability of n arrivals in T time periods
λ = Average numbers of cutomer arrivals per period

Service time distribution

$$P_{(t \leq T)} = 1 - e^{-\mu T}$$

μ = Average number of customers completing service per period
t = service time of the customer
T = target service time

Single server model

Average utilization of the system

$$\rho = \frac{\lambda}{\mu}$$

Average number of customers in the system

$$L = \frac{\lambda}{\mu - \lambda}$$

Average number of customers in the waiting line

$$L_q = \rho L = \frac{\lambda^2}{\mu(\mu - \lambda)}$$

Average time spent in the system including service

$$W = \frac{1}{\mu - \lambda}$$

Average waiting time in line

$$W_q = \rho W = \frac{\lambda}{\mu(\mu - \lambda)}$$

Probability that n customers are in the system

$$P_n = (1 - \rho)\rho^n$$

Probability that 0 customers are in the system

$$P_0 = 1 - \frac{\lambda}{\mu}$$

Probability that less than *k* customers are in the system

$$P_{n<k} = 1 - \left(\frac{\lambda}{\mu}\right)^k$$

Probability of more than *k* customers are in the system

$$P_{n>k} = \left(\frac{\lambda}{\mu}\right)^{k+1}$$

MRP

Item:	Week:	1	2	3	4	5	6	7	8
	Due:								
	Release:								

Item:	Week:	1	2	3	4	5	6	7	8
	Due:								
	Release:								

Item:	Week:	1	2	3	4	5	6	7	8
	Due:								
	Release:								

Item: Lot size:
Lead time:
Safety stock:

Week:		1	2	3	4	5	6	7	8
Gross requirements									
Scheduled reciepts									
Projected on hand									
Planned reciepts									
Planned order releases									

Item: Lot size:
Lead time:
Safety stock:

Week:		1	2	3	4	5	6	7	8
Gross requirements									
Scheduled reciepts									
Projected on hand									
Planned reciepts									
Planned order releases									

Item: Lot size:
Lead time:
Safety stock:

Week:		1	2	3	4	5	6	7	8
Gross requirements									
Scheduled reciepts									
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Planned reciepts									
Planned order releases									

Item: Lot size:
Lead time:
Safety stock:

Week:		1	2	3	4	5	6	7	8
Gross requirements									
Scheduled reciepts									
Projected on hand									
Planned reciepts									
Planned order releases									