Examination

Course:	Production and Logistics Planning
Date:	2019-06-14
Number of hours:	5 hours
Group:	Freestanding course
Course codes:	PPU426, PPU411, KPP227
Examination code:	TEN1
Help Means:	Calculator, Dictionary, Ruler
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Please make your calculations on Graph paper.

Max points: 100p

Number of points for each task is denoted within parenthesis.

Swedish-grades

Grade 3: at least 50%

Grade 4: at least 65%

Grade 5: at least 85%

ECTS-grades

E: at least 50%

D: at least 60%

C: at least 70%

B: at least 80%

A: at least 90%

1. Theory of constraints (6p)

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

2. Forecasting (7p)

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:	98	82	106	112	104	112	121	123

a) Use the exponential smoothing method to forecast the number of units for June - January. The initial forecast for May was 105 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 as of the end of December.

3. Linear regression (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 34 teeth. Use linear regression to estimate how long the cutting time will be for that gear.

Number of teeth	Cutting time
25	112
17	86
12	54
28	132
14	70
13	60
21	100

4. Capacity planning – Decision Tree (6p)

As the global competition increases for Company A, a decision must be made to either outsource parts of production to a low cost country or keep all production in-house. If the company were to outsource parts of production to India, the advantages of low material cost and low labour cost can result in cheaper products which will attract new customers. Probability of this happening is 0.3 and there is no reason to make any adjustment (payoff = 350 000 SEK). On the other hand, even as new customers are attracted due to the low cost of products, the quality issues correlated with outsourcing parts of production might cause existing customers to reconsider staying with the company. The probability of this happening is 0.7. In this case the manager have two options, either invest in extensive education of the personnel in India (payoff = 200 000 SEK). The other option is to target a new market in India, however this can result in two outcomes, either the competition in the new market is low with a probability of 0.4 (payoff = 400 000 SEK) or the competition is high with a probability of 0.6 (payoff = 50 000 SEK).

In contrast to outsource parts of production, the manager considers to keep all parts of production in-house. This have two outcomes, either existing customers continue to be loyal, with a probability of 0.4. Or the existing customers abandon the company with a probability of 0.6. If the existing customers continue to be loyal, the manager can strengthen the company's position by choosing either to cut down costs on processes which are not value-adding (payoff = 400 000 SEK) or to lay of personnel (payoff = 35 000 SEK). If the customers start to abandon the company, the manager is faced with two decisions, either to focus on the core business (payoff = 200 000 SEK) or to enter new markets. However when enter a new market in Sweden, the competition can be either high with a probability of 0.7 (payoff = 50 000 SEK) or low, with a probability of 0.3 (payoff = 500 000 SEK).

a) Draw a decision tree for this problem.

b) Analyse the decision tree to determine the expected payoff for each decision and event node. Recommend if the manager should outsource or keep parts of production in-house with regard to the highest expected payoff. Motivate your answer.

5. Waiting lines (6p)

The purchasing department is re-evaluating their approach of handling outgoing orders. To satisfy the extensive customer demand, the department must process at an average 8 outgoing orders daily. During a workday of 8 hours, the department ordinary receives 3 orders per hour. The employee responsible for processing orders can complete 4 order per hour.

a) What is the probability that 8 orders will arrive to the department during any hour?

b) What is the probability that an order will need less than 15 minutes of processing time?

c) Using a single server model with Poisson distribution, calculate the *average waiting time in line* for orders and *probability of more than 8 and 9 orders in the system*?

6. Location (6p)

A production facility in Köping is parts supplier to a number of companies. As transportation costs is one of the company's highest costs, the manager considers to relocate the facility in order to be close to its 8 customers. The customer's location is shown below:

Customer location	Tons shipped	x,y Coordinates
Arboga	15 000	(3, 15)
Kungsör	86 000	(8, 3)
Göteborg	110 000	(15, 13)
Skövde	66 000	(7, 14)
Örebro	78 000	(3, 8)
Trollhättan	48 000	(11, 9)
Finnspång	33 000	(9, 10)
Västerås	90 000	(2, 6)

a) Find the centre of gravity for the production facility.

b) Using the rectilinear distance, what is the load-distance score for this location?

7. Transportation method (8p)

A manufacturing company has three factories that supply four major warehouses. The capacity of each factory, and the demand of each warehouse, and transportation cost, is listed in the table below. Use the Modified Transportation Method (MODI) to optimise the distribution of goods from the factories to the warehouse. (Solve in the attached template and remember to turn in your solution!)

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

8. Scheduling (6p)

Consider the following job times for a two-machine problem. Assume that the jobs are processed in the sequence M1-M2. Find the optimum sequence for processing the five jobs below and show it in a Gantt-chart for both machines, indicating the total processing time.

Job	M1	M2
A	12	24
B	15	8
C	6	18
D	9	20
E	12	9

9. MRP (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.

10. EOQ (8p)

The production planner of a machining factory must determine the lot size for a particular component that has a steady demand of 60 components per day. The production rate is 380 components per day, annual demand is 15000 components, setup cost is $200, annual holding cost is $1 per component, and the plant operates 250 days per year. Determine the following:

a) The economic production lot size.

b) The total annual setup and inventory holding cost for this economic lot size.

c) The time between orders.

d) The production time per lot.

11. EOQ with discount (6p)

As an inventory manager you must decide on the order quantity for an item that has an annual demand of 3000 units. Placing an order cost you €40 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
1 – 500	€ 5:20
501 – 2000	€ 4:70
2001 – 2500	€ 3:50
2501 -	€ 2:20

What is the best order policy from a cost perspective?

12. Line balancing (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 workstations?
d) Use **Ranked Positional Weight** and balance the line. Which work elements are assigned to which station?
e) What is the efficiency of your solution?

13. Aggregate planning (6p)

Name the 3 main steps for developing the best aggregate plan.

14. Aggregate planning (8p)

A large distribution center must develop a staffing plan that minimizes total costs using part-time stockpickers. Each part-time employee can work a maximum of 20 hours per week on regular time. Use chase strategy and level and compute the total cost. For the level strategy, the manager wants to meet the demand with the minimum use of undertime.

	1	2	3	4	5	6	Total
Forecast demand	6	12	18	15	13	14	78

Currently, 10-part-time clerks are employed. They have not been subtracted from the forecast demand shown. Constraints and cost information are as follows:

a) The size of training facilities limits the number of new hires in any period to no more than 10.

b) No backorders are permitted.

c) Overtime cannot exceed 20 percent of the regular-time capacity in any period.

d) The followings costs can be assigned:

Regular-time wage rate	$2000/time period at 20 hours/week
Overtime wages	150% of the regular-time rate
Hires	$1000 per person
Layoffs	$500 per person

15. Layout (5p)

Name five reasons for redesign a layout.

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

Line balancing

$$CT = \frac{Available\ time}{Production\ demand}$$

$$Number\ of\ workstations = \frac{Total\ process\ time}{Cycle\ time}$$

$$efficiency = \frac{Total\ process\ time}{Number\ of\ WS \times CT}$$

Forecasting formulas

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

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

Waiting lines

Interarrival times

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

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

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

D / C		Distributors			
Factories					

D / C		Distributors			
Factories					

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Factories					

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Factories					

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Factories					

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Factories					

D / C		Distributors			
Factories					

D / C		Distributors			
Factories					

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									
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									