5 Exercise layout (CONTD)

Product	Routing	Forecast Production (units / week)	# trips
1	A - B - C - D - E	200	4
2	A - D - E	900	18
3	A - B - C - E	400	8
4	A - C - D - E	650	13

All products are produced in batches of size 50

a) from - to chart

If there is no direct connection between 2 departments, the parts must be routed through other departments to get to their destination.
→ product 1, 3 and 4 have routing A B C D E, for product 2 routing A D E is possible

→ for products 1, 3, 4

\# trips of
A → B : 4 + 8 + 13 = 25
A → D : 18
B → C : 4 + 8 + 13 = 25
C → D : 4 + 8 + 13 = 25
D → E : 4 + 18 + 8 + 13 = 43

→

From \ To	A	B	C	D	E
A		25		18	
B			25		
C				25	
D					43
E					

b) from-to chart giving materials handling cost per week between departments

\+ Cost of transporting goods = $\boxed{\$2/\text{foot}}$

	A	B	C	D	E
A		45		89	
B			32		
C				52	
D					67
E	56				

	A	B	C	D	E
A		25		18	
B			25		
C				25	
D					43
E					

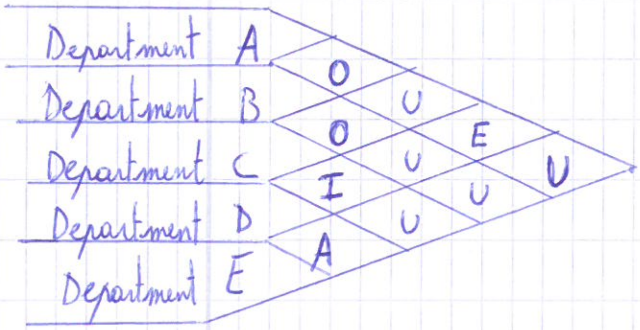
	A	B	C	D	E
A		2250		3204	
B			1600		
C				2600	
D					5762
E	0				

$= 45 \times 25 \times 2 = 2250$

$= 89 \times 18 \times 2 = 3204$

c) activity relationship chart. Only use rankings A, E, I, O, U

highest cost — lowest cost



	A	B	C	D	E
A		2250		3204	
B			1600		
C				2600	
D					5762
E	0				

A = 5762 → highest cost
E = 3204 → 2nd
I = 2600 → 3rd
O = 2250, 1600 : 2 lowest costs
U ⇒ no transport / relation

d) Different layout ?

Yes: move D to the middle: closer to A & E
⇒ lowers the costs of transport between A − D
C − D

Les 5: Location planning and analysis

$\boxed{1}$ Central city location : fixed monthly costs = \$ 7000
~~Outsi~~ " " : transportation costs = \$ 30 / car
Outside location : fixed monthly costs = \$ 4700
" " : transportation costs = \$ 40/car

Dealer price = \$ 90/car

a) 1) demand = 200

- City : $200(90-30) - 7000 = 5000$
- Outside : $200(90-40) - 4700 = 5300$

→ outside is better

2) demand = 300

- City : $300(90-30) - 7000 = 11\,000$
- Outside : $300(90-40) - 4\,700 = 10\,300$

→ City is better

b) Same monthly profit for which volume of output?

$Q(90-30) - 7000 = Q(90-40) - 4700$

→ when are both functions equal to eachother?

$$60Q - 7000 = 50Q - 4700$$
$$10Q = 2300$$
$$Q = 230 \text{ cars}$$

2 a)

Factor	Location score A	B	C
(1) Business services	9	5	5
(2) Community "	7	6	7
(3) Real estate cost	3	8	7
(4) Construction "	5	6	5
(5) Cost of living	4	7	8
(6) Taxes	5	5	4
(7) Transportation	6	7	8

Which one is best when all factors are weighted equally?

Sum of factors: $A = 9+7+3+5+4+5+6 = 39$
$B = 44$
$C = 44$

Avarage of factors: $A = 39/7 = 5,57$
$B = 44/7 = 6,29$
$C = 44/7 = 6,29$

=> Location B or C is best, followed by A.

b)

Factor	Weight	A	B	C
(1)	2/9	18/9	10/9	10/9
(2)	1/9	7/9	6/9	7/9
(3)	1/9	3/9	8/9	7/9
(4)	2/9	10/9	12/9	10/9
(5)	1/9	4/9	7/9	8/9
(6)	1/9	5/9	5/9	4/9
(7)	1/9	6/9	7/9	8/9
Weighted average of factors = Sum	1	53/9	55/9	54/9

=> Location B is best, followed by C and then A.

25

3 Center of gravity : which one is the better site ?

Destination	Quantity
D1 (1,2)	900
D2 (2,4)	300
D3 (3,1)	700
D4 (4,2)	600
D5 (5,3)	1200
$(x_i ; y_i)$	3700

(coordinates)

- <u>Center of gravity</u>

$$\bar{x} = \frac{\sum x_i Q_i}{\sum Q_i} = \frac{1 \cdot 900 + 2 \cdot 300 + 3 \cdot 700 + 4 \cdot 600 + 5 \cdot 1200}{3700} = 3,2$$

$$\bar{y} = \frac{\sum y_i Q_i}{\sum Q_i} = \frac{2 \cdot 900 + 4 \cdot 300 + 1 \cdot 700 + 2 \cdot 600 + 3 \cdot 1200}{3700} = 2,3$$

- Use the map to determine the coordinates for L1 & L2. Use ruler if neccesary

L_1 coordinates $\approx (2,6 ; 2,4)$
L_2 " $\approx (3,5 ; 2,5)$
And $(\bar{x}, \bar{y}) = (3,2 ; 2,3)$

How far from center of gravity?
$= \sqrt{(x_i - \bar{x})^2 + (y_i - \bar{y})^2}$

$\Rightarrow$

$$\begin{cases} \text{for } L_1 : \sqrt{(2,6-3,2)^2 + (2,4-2,3)^2} = 0,608 \\ \text{for } L_2 : \sqrt{(3,5-3,2)^2 + (2,5-2,3)^2} = 0,361 \end{cases}$$

$\Rightarrow$ Which site is closer to the center of gravity (lowest value!) ?

$\Rightarrow$ L_2 is closer to the center of gravity

Les 6: Inventory - deterministic

1 ABC-classification

Category A: (10-15%) of the items with highest value
B: ± 35% of the items
C: ±50% of the items with lowest value

Monthly usages

Item	Usage	Unit Cost	1) Monthly dollar value
4021	90	$ 1400	$ 126 000
9402	300	12	3600
4066	30	700	21 000
6500	150	20	3000
9280	10	1020	10200
4050	80	140	11 200
6850	2000	10	20 000
3010	400	20	8 000
4400	5000	5	25 000

2) Arrange monthly dollar values in descending order

Item	Monthly dollar value	Category	% of items	% of monthly dollar value
4021	$ 126 000	A	1/9 = 11,11%	$\frac{126000}{228000} = 55,26\%$
4400	25 000	B	3/9 = 33,33%	$\frac{66000}{228000} = 28,95\%$
4066	21 000			
6850	20 000			
4050	11 200	C	5/9 = 55,56%	$\frac{36000}{228000} = 15,79\%$
9280	10 200			
3010	8 000			
9402	3600			
6500	3000			
	228 000		100%	100%

9 items ⇒ 1 item = 1/9 = 11,11%

$\boxed{2}$ EOQ (Economic Order Quantity)

9000 pots/year

Usage: 750 pots/month = D

Purchase cost: \$2/pot = P

Carrying costs per pot = 30% of cost (annual) = 0,3 x 2 = 0,6 \$ $\frac{\text{per unit}}{\text{year}}$ → H

Ordering costs = \$20 per order = S

Order size of 1500 flower pots = Q

a) Additional annual cost?

1) EOQ?

*) $Q_0 = \sqrt{\frac{2DS}{H}} = \sqrt{\frac{2 \cdot (9000) \cdot 20}{0{,}60}} = 775$ pots

*) $TC = \frac{Q}{2} \cdot H + \frac{D}{Q} S = \frac{775}{2} \times 0{,}60 + \frac{9000}{775} \times 20$

with Q_0 $= \$\,464{,}76$

*) $TC = \frac{Q}{2} \cdot H + \frac{D}{Q} \cdot S = \frac{1500}{2} \times 0{,}60 + \frac{9000}{1500} \times 20$

with order size given $= \$\,570$

⇒ additional annual cost: \$570 − \$464,76 = \$105,24

b) Other benefits?

⇒ benefit of using EOQ is that about one half of the storage space would be needed (you can use the other half for something else)

3 EPQ (Economic Production Quantity)

u = usage rate = 20 tons / day = $2000 \times 20 = 40\,000 \dfrac{\text{pounds}}{\text{day}}$ $\downarrow /100$

= 400 bags per day

p = production rate = 50 tons/day = $2000 \times 50 = 100\,000$ pounds/day $\downarrow /100$

= 1000 bags per day

$D = 400 \dfrac{\text{bags}}{\text{day}} \times 200 \dfrac{\text{days}}{\text{year}} = 80\,000$ bags/year

$S = 100\,\$$

$H = \$5$/ton per year $\Rightarrow \dfrac{\$5 \text{ per ton per year}}{20 \text{ bags per ton}}$ $\Rightarrow 2000/100$

$= \$0,25$ per bag per year

a) How many bags are optimal?

$$Q_p = \sqrt{\frac{2DS}{H}} \times \sqrt{\frac{p}{p-u}} = \sqrt{\frac{2(80\,000).100}{0,25}} \times \sqrt{\frac{1000}{1000-400}}$$

$= 10327,97 = 10328$ bags

b) Average inventory for this lot size

$$I_{max} = \frac{Q_p}{p}(p-u) = \frac{10328}{1000}(1000-400) = 6196,8 \text{ bags}$$

$$\Rightarrow I_{average} = \frac{I_{max}}{2} = \frac{6196,8}{2} = 3098,4 \text{ bags}$$

c) Run lenght?

$$\text{Run time} = \frac{Q_r}{r} = \frac{10328}{1000} = 10,33 \text{ days}$$

d) Runs per year: $\frac{D}{Q} = \frac{80000}{10328} = 7,75$ runs per year

e) Setup cost reduced to \$25 per run? Annual saving?

(1) $(S = \$25)$ $TC_{min} = \left(\frac{I_{max}}{2}\right) \cdot H + \left(\frac{D}{Q}\right) \cdot S = \left(\frac{3098,4}{2}\right) \times 0,25 + \frac{80000}{5164} = 774,60$

?

$(S = \$25)$ $Q_r = \sqrt{\frac{2 \cdot 80000 \cdot 25}{0,25}} \sqrt{\frac{1000}{1000-400}} = 5164$ bags

$(S = \$25)$ $I_{max} = \frac{5164}{1000}(1000-400) = 3098,4$

(2) $(S = \$100)$ $TC_{min} = \left(\frac{I_{max}}{2}\right) \cdot H + \left(\frac{D}{Q}\right) \cdot S$

$$= \left(\frac{6196,8}{2}\right) \times 0,25 + \left(\frac{80000}{10328}\right) \cdot 100 = 774,60 + 774,59$$

$$= 1549,19$$

=> Annual savings = 1549,19 − 774,60 = 774,59

4 Quantity discounts

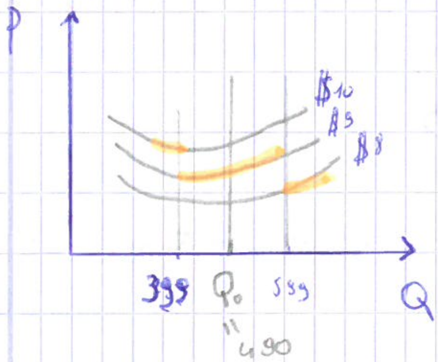
$u = 25 \frac{\text{stones}}{\text{day}}$

$D = 25 \frac{\text{stones}}{\text{day}} \times 200 \frac{\text{days}}{\text{year}} = 5000 \text{ stones / year}$

$S = \$48$

# orders	price (P)
1 - 399	\$ 10
400 - 599	\$ 9
600 +	\$ 8

a) $H = \$2$ per year per stone ⇒ Quantity that minimizes total annual cost?



$\Rightarrow Q_o = \sqrt{\frac{2DS}{H}} = \sqrt{\frac{2 \cdot 5000 \cdot 48}{2}}$

$= 490$ stones

⇒ Determine TC for minimum point and for price breaks of all lower unit costs.

⇒ Check total cost for 490 stones and 600 stones (higher # orders, with higher discount) to see which one is lower

*) $TC(490) = \frac{Q}{2}H + \frac{D}{Q}S + PD = \frac{490}{2} \times 2 + \frac{5000}{490} \times 48 + 9 \times 5000$

$= 45979,80$

*) $TC(600) = \frac{Q}{2}H + \frac{D}{Q} \cdot S + P \cdot D = \frac{600}{2} \times 2 + \frac{5000}{600} \times 48 + 8 \times 5000$

$= 41000$

⇒ Conclusion: Optimal order quantity = 600 stones

b) carrying costs = 30% of unit cost ⇒ Optimal order size ?

$H = 0{,}3 \cdot p$

(1) Beginning with the lowest unit price, compute the minimum points for each price range, until you find a feasible minimum point

*) Minimum point for $P = \$8$

$$Q_0 = \sqrt{\frac{2DS}{H}} = \sqrt{\frac{2 \cdot 5000 \cdot 48}{0{,}3 \cdot 8}} = 447{,}21 = 447$$

Not feasible, since this quantity is not higher than 600 !
⇒ need at least a size of 600 to get the price of $\frac{\$8}{\text{unit}}$

*) Minimum point for $P = \$9$

$$Q_0 = \sqrt{\frac{2DS}{H}} = \sqrt{\frac{2 \cdot 5000 \cdot 48}{0{,}3 \cdot 9}} = 421{,}64 = 422$$

= feasible since this is in the order range of $P = \$9$ (400 – 599)

(2) Compare the total cost at $Q = 422$ to $Q = 600$

$$TC_{422} = \frac{Q}{2}H + \frac{D}{Q}S + PD = \frac{422}{2} \times (0{,}3 \times 9) + \left(\frac{5000}{422}\right) \times 48 + 9 \times 5000 = 46\,138{,}42$$

$$TC_{600} = \frac{Q}{2}H + \frac{D}{Q}S + PD = \frac{600}{2} \times (0{,}3 \times 8) + \frac{5000}{600} \times 48 + 8 \times 5000 = 41\,120$$

⇒ Conclusion : optimal order quantity = 600 stones

c) ROP (reorder point)

$ROP = d \times LT$

d = demand rate
LT = lead time in days / weeks

$ROP = 25$ stones/day $\times$ 6 days
$= 150$ stones.

Les 7: Inventory: stochastic

[1] Usage rate = 800 feet/day
LT = 6 days
Service level = 95%

Continuous review

ROP?

Safety stock	Stockout risk	Service level
1500	0,10	0,90
1800	0,05	0,95
2100	0,02	0,98
2400	0,01	0,99

→ To have a service level of 95%, a safety stock of 1800 is needed.

→ ROP = expected demand during lead time + safety stock

$= 6 \times 800 + 1800 = 6600$ feet.

[2] Service level

Expected demand during LT = 300 units
σ_{dLT} = Standard deviation of LT demand = 30 units
LT = distributed normally

a) ROP with 1% risk of stockout during LT ⟹ 1% risk ⟹ 99% service level

⇓

$z = 2,33$
(closest to 99% = 0,9901)

⟹ find this in the table

ROP = expected demand during LT + safety stock
$= 300 + z.\sigma_{dLT}$
$= 300 + z.30$
$= 300 + 2,33 \cdot 30$
$= 369,9 \approx 370$ (round up)

b) safety stock needed to have a 1% risk of stockout during LT

Service level = 99%

↳ Safety stock $= z \cdot \sigma_{dLT}$

$= 2,33 \times 30 = 69,9 \approx 70$

c) Service level of 98% is lower, so less safety stock would be needed and the ROP would be smaller.

$\boxed{3}$ Continuous and periodic review

- Normal distribution (Demand) (work in weeks)
- Mean = 21 gallons/week (Demand) → 3 gallons/day
- $\sigma = 3,5$ gallons/week (Demand)
- Service level needed = 90%
- LT = 2 days $= \frac{2}{7}$ week
- Open: 7 days a week

a) ROP? Desired service level = 90% → $z = 1,28$ ($F(1,28) = 0,8997$) ← closest to 90%

Demand = variable, LT = constant

$$\Rightarrow ROP = \bar{d} \times LT + z\,\sigma_d \sqrt{LT}$$

= exp. dem. during LT + safety stock

$$= 21 \times \frac{2}{7} + 1,28 \cdot 3,5 \sqrt{2/7} = 8,39 \text{ gallons} \approx 9$$

→ How many days of supply are on hand at ROP?

$$= \frac{ROP}{\text{Average daily demand}} = \frac{9}{3} = 3 \text{ days}$$

b-) Fixed-interval model : Size needed for 90% service level with order interval of 10 days and Supply of 8 gallons on hand at the time of order ?

→ Q?

→ probability of stockout before this order arrives ?

Q = expected demand during protection interval + safety stock − amount on hand at reorder point (A)

*) $Q = \bar{d}\,(OI + LT) + z\sigma_d\sqrt{OI + LT} - A$

OI = order interval

$Q = 21 \times \left(\frac{\overset{\text{in weeks}}{10+2}}{7}\right) + 1{,}28 \times 3{,}5 \times \sqrt{\frac{10+2}{7}} - 8$

$= 33{,}87$ gallons $\approx \boxed{34}$

**) ROP (demand uncertain)

$\hookrightarrow = \bar{d} \times LT + z\sigma_d\sqrt{LT}$

$8 = 21 \times \frac{2}{7} + z \times 3{,}5 \times \sqrt{2/7} \Rightarrow z = \frac{2}{1{,}871} = 1{,}07$

They reorder when they have 8 gallons left

See table

Lead time service level = 85,77 %

c) ROP model :

After one day, order will be 2 days later + 2 gallons have been sold since the order had been placed

After 1 day, quantity on hand = 9 - 2 = 7 gallons

↳ probability of running out of stock?

$$ROP = 7 = \bar{d} \times LT + z\sigma_d \sqrt{LT}$$
$$= 21 \times \frac{2}{7} + z \times 3{,}5 \times \sqrt{2/7}$$

$$\Rightarrow z = \frac{1}{1{,}871} = 0{,}53 \xrightarrow{(*)} \text{lead time service level is } 0{,}7019$$

(*) see figure

$$\Rightarrow \text{risk of stockout} = 1 - 0{,}7019 = 29{,}81\%$$

$\boxed{4}$ Newsboy problem with discrete distribution

Demand	0	1	2	3
Probability	0,15	0,35	0,30	0,20

a) Ratio method

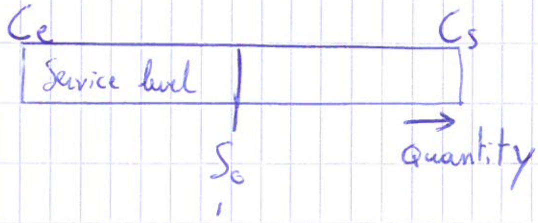
C_s = revenue / unit − cost / unit
$= 60 - 33$
$= 27$

C_e = original cost / unit − salvage value / unit
$= 33 - (\frac{1}{2} \times \frac{1}{3} \times 60)$
$= 23$

Demand	0	1	2	3
Cumul. Prob.	0,15	0,50	0,8	1,00

Service level $= \dfrac{C_s}{C_s + C_e}$

where C_s = shortage cost / unit
C_e = excess cost / unit



Balance point
= Optimum stocking quantity

$$SL = \frac{C_s}{C_s + C_e} = \frac{27}{27+23} = 0{,}54 = \text{between } 1 \,\&\, 2$$

⇒ Stock 2 cakes

b) Tabular method

If the stocking level is	Demand = 0 prob = 0,15	Demand = 1 prob. = 0,35	Demand = 2 prob = 0,30	Demand = 3 prob = 0,20	Expected payoff
0	S = D $0	Sell 0, over 0 (0,35 x 0 x 27) - (0,35 x 0 x 23) = $0	Sell 0, over 0 (0,3 x 0 x 27) - (0,3 x 0 x 23) = $0	Sell 0, over 0 (0,20 x 0 x 27) - (0,2 x 0 x 23) = $0	$0
1	Sell 0, over 1 (0,15 x 0 x 27) - (0,15 x 1 x 23) = -$3,45	Sell 1, over 0 (0,35 x 1 x 27) - (0,35 x 0 x 23) = $9,45	Sell 1, over 0 (0,30 x 1 x 27) - (0,30 x 0 x 23) = $8,10	Sell 1, over 0 (0,20 x 1 x 27) - (0,20 x 0 x 23) = $5,40	$19,50 = sum of
2	Sell 0, over 2 (0,15 x 0 x 27) - (0,15 x 2 x 23) = -$6,90	Sell 1, over 1 (0,35 x 1 x 27) - (0,35 x 1 x 23) = $1,40	Sell 2, over 0 (0,30 x 2 x 27) - (0,30 x 0 x 23) = $16,20	Sell 2, over 1 (0,20 x 2 x 27) - (0,20 x 1 x 23) = $10,80	$21,50
3	Sell 0, over 3 (0,15 x 0 x 27) - (0,15 x 3 x 23) = -$10,35	Sell 1, over 2 (0,35 x 1 x 27) - (0,35 x 2 x 23) = -$6,65	Sell 2, over 1 (0,30 x 2 x 27) - (0,30 x 1 x 23) = $9,30	Sell 3, over 0 (0,20 x 3 x 27) - (0,20 x 0 x 23) = $16,20	$8,50

⇒ Stock 2 cakes !

$\boxed{5}$ Newsboy problem with normal distribution

*) 18 ticketholders cancel (on average)
*) Cancellation ≈ normal distribution with a mean of 18 and standard deviation of 4,55
*) Profit / passenger = \$99

*) Cash payment of \$200 if it's actually overbooked (for 1 seat)

→ How many tickets should be overbooked?
Note: a cancellation = demand for overbooking

C_s = \$99 = cost you lose if you do not have enough tickets overbooked
C_e = \$200 = cost you have if there are too many tickets overbooked.

$$\text{Ratio}: SL = \frac{C_s}{C_s + C_e} = \frac{99}{99+200} = 0{,}3311 \rightarrow z = -0{,}44$$

$$S_0 = \text{mean} + z\sigma$$
$$= 18 + (-0{,}44 \times 4{,}55) = 15{,}998 \approx 16 \text{ tickets to overbook}$$

6 Newsboy problem

4 machines
profit = \$ 10/day

Demand	Frequency
0	0,3
1	0,2
2	0,2
3	0,15
4	0,10
5	0,05
	1,00

a)

Demand	0	1	2	3	4 (4 machines)	5
Cumul. prob	0,30	0,5	0,7	0,85	0,95	1,00

⇒ for 4 machines to be optimal, the SL ratio must be between $>0,85$ and $\leq 0,95$

$$SL = \frac{10}{10 + C_e} = 0,85 \rightarrow C_e = \$1,76$$

$$SL = \frac{10}{10 + C_e} = 0,95 \rightarrow C_e = \$0,53$$

⇒ Implied range of excess cost : $0,53 < C_e < 1,76$

b) C_e range is judged to be too low. If C_e is actually higher, having too much is more costly, and the number of machines should be decreased. The optimal service level will also decrease.