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Oefeningen logistiek & SCM

Les 1 : Introduction

$\boxed{1}$ a) labor productivity : 1) $\frac{300}{8} = 37,5$ 2) $\frac{240}{6} = 40 \frac{\text{meals}}{\text{worker}}$

b) Layout of the facilities, worker skill / experience, worker satisfaction, quality delivered, ...

$\boxed{2}$ Labor productivity for each week

week 1 : $96/4 = 24$
" 2 : $72/3 = 24$
" 3 : $92/4 = 23$
week 4 : $50/2 = 25$
" 5 : $69/3 = 23$
" 6 : $52/2 = 26$

A crew size of 2 workers seems to work best w an avarage of 25,5
" " " 3/4 " only has an avarage production of 23,5

$\boxed{4}$ a) 1) $\frac{80}{5} = 16$ $\frac{84}{4} = 21$ carts per worker per hour

b) 1) $\frac{80 \text{ carts}}{90 \$} = 0,89$ $\frac{84 \text{ carts}}{90 \$} = 0,93$ carts per dollar cost

c) Labor productivity growth = $\frac{21}{16} = 1,3125 \Rightarrow 31,25\%$
Multifactor productivity growth
$= \frac{0,93}{0,89} = 1,0449 \Rightarrow 4,49\%$

The multifactor productivity measure is more relevant

$\boxed{7}$ a)

	Labor productivity	Multifactor productivity
A)	$36/4 = 9$	$36/(25 \times 4 \times 8) + 1.(25 \times 4 \times 8) + 36 \times 5 = 0{,}020$
B)	$40/5 = 8$	0,018
C)	$60/8 = 7{,}5$	0,017
D)	$20/3 = 6{,}67$	0,015

b)

$40/4 = 10$	0,022
$45/5 = 9$	0,020
$68/8 = 8{,}5$	0,019
$23/3 = 7{,}67$	0,017

$\boxed{\text{Case}}$ a) Highest productivity

1) $\frac{4234}{2} = 2117$

2) $\frac{5352}{3} = 1784$

3) $\frac{7860}{4} = 1965$

in square feet per day

Larger crews may lead to more standing around and talking and workers might be getting in the way of eachother
It could be that workers are more productive if they work in pairs

b) Rationale: shorter flow time, better responsiveness, impress the customer

c) Qualitative issues: skills of the workers, team synergy: did the people work together well!

Les 2: Forecasting

[1] a) $F_{16}^{muffins} = 33$ (use the last order)
$F_{16}^{buns} = 33 + 2$ (change from previous value)
$F_{16}^{cupcakes} = 47$
↓
16 will be a rise again (every 4 orders), maybe something seasonal?

b) Sales adequately reflect demand. We are assuming that no stockouts occurred because demand equals sales if there are no shortages.

[2] Stable data so you use naive, moving average, exp. smoothing

a) $F_6 = 22$ (use last request as forecast

b) $F_6 = \frac{22 + 18 + 21 + 22}{4} = 20,75$ (4-period moving average)

c) Exponential smoothing with $\alpha = 0,30$ and 20 for week 2 forecast
$\alpha = 0,30$ $\quad$ $\underline{F_2 = 20}$

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

$$F_3 = F_2 + \alpha \, (A_2 - F_2)$$
$F_3 = 20 + 0,3(22 - 20)$
$F_3 = 20,6$
$F_4 = 20,6 + 0,30 \, (18 - 20,6)$
$F_4 = 19,82$
$F_5 = 19,82 + 0,30 \, (21 - 19,82)$
$F_5 = 20,17$
$F_6 = 20,17 + 0,30 \, (22 - 20,17)$
$F_6 = 20,72$

$\boxed{3}$ Trend - adjusted exponential smoothing model

$\alpha = 0,5$ $\beta = 0,4$ $TAF_5 = 250$

$TAF_{t+1} = S_t + T_t$ with S_t = previous forecast plus smoothed error
T_t = current trend estimate

AND

$S_t = TAF_t + \alpha (A_t - TAF_t)$

$T_t = T_{t-1} + \beta (TAF_t - TAF_{t-1} - T_{t-1})$

$TAF_6 = S_5 + T_5 \rightarrow$ staat in opgave (meestal niet) $= 10$

$\rightarrow TAF_5 + \alpha (A_5 - TAF_5)$

$\rightarrow 250 + 0,5 (255 - 250) = 252,5$

$TAF_6 = 252,5 + 10 = 262,5$

$TAF_7 = S_6 + T_6$

met $S_6 = TAF_6 + 0,5 (265 - TAF_6) = 262,5 + 0,5 (265 - 262,5)$

$S_6 = 263,75$

$T_6 = T_5 + \beta (TAF_t - TAF_{t-1} - T_{t-1})$

$T_6 = 10 + 0,4 (262,5 - 250 - 10)$

$= 11$

$TAF_7 = 263,75 + 11 = 274,75$

$TAF_8 = S_7 + T_7$

met $S_7 = 274,75 + 0,5 (272 - 274,75) = 273,38$

$T_7 = 11 + 0,4 (274,75 - 262,5 - 11) = 11,5$

$TAF_8 = 273,38 + 11,5 = 284,88$

$TAF_9 = S_8 + T_8$

met $S_8 = 284,88 + 0,5(285 - 284,88) = 284,94$

$T_8 = 11,5 + 0,4(284,88 - 274,75 - 11,5) = 10,95$

$TAF_9 = 295,89$

$TAF_{10} = S_9 + T_9$

met $S_9 = 295,89 + 0,5(294 - 295,89) = 294,95$

$T_9 = 10,95 + 0,4(295,89 - 284,88 - 10,95) = 10,97$

$TAF_{10} = 305,92$

$\boxed{4}$ → Seasonal methods

* gem. van een vorige dataset vergelijken met dataset (vb. bepaalde dag)

This is for b) Avarages per day: $MON = \frac{80 + 82 + 84 + 87}{4} = 83,25$

$TUE = \frac{75 + 77 + 78 + 82}{4} = 78$

$WED = 82,25$

$THU = 96$

$FRI = 135$

$SAT = 139,25$

$SUN = 42,5$

Total avarage : $\frac{\Sigma \text{ all days}}{21} = 93,893$

a) $MON = \frac{\Sigma \text{ indices on monday}}{\text{total indices of monday}} = \frac{0,8982 + 0,9032 + 0,9022}{3} = 0,9012$

$TUE = \frac{\Sigma \text{ indices on tuesday}}{\text{amount of indices on tuesday}} = \frac{0,8422 + 0,8336 + 0,8392}{3} = 0,8383$

$WED = \frac{0,8736 + 0,8830 + 0,8953}{3} = 0,8840$

$$THU = \frac{1{,}0489 + 1{,}0233 + 1{,}0181 + 1{,}0014}{4} = 1{,}0229$$

$FRI = 1{,}4260$

$SAT = 1{,}4820$

$SUN = 0{,}4496$

Sum = 7,004

⇒ I don't know how to get the normalized indices? Any help?

Normalized values: Mon = 0,9007 Thu = 1,0223 Sun = 0,4493
Tue = 0,8378 Fri = 1,4252
Wed = 0,8835 Sat = 1,4812

SUM = 7,000

b) $\dfrac{\text{Avarages per day}}{\text{Total avarage}}$ ⇒ *) $\dfrac{\text{Monday}}{\text{Total}} = \dfrac{83{,}25}{93{,}893} = 0{,}89$

↳ SA - method
Seasonal avarage

*) Tuesday = 78 / 93,893 = 0,83
*) Wednesday = 82,250 / 93,893 = 0,88
*) Thursday = 96 / 93,893 = 1,02
*) Friday = 135 / 93,893 = 1,44
*) Saturday = 139,25 / 93,893 = 1,48
*) Sunday = 43,5 / 93,893 = 0,46

Sum = 7,000

c) Forecast day 29?
→ deseasonalize then naive method / or moving avarage / or exp. smoothing and reincorporate the seasonality effect

naive method ← A_{28} ↱ seasonal avarage Monday

$$F_{29} = \frac{48}{0{,}46} \times 0{,}89 = 93$$

↳ seasonal avarage Sunday

$\alpha = 0,1$

mean absolute deviation

5

t month	e error	$\lvert e \rvert$	Cum error $= \Sigma$ error	MAD_t	Tracking signal	
1	-8	8	-8			
2	-2	2	-10			
3	4	4	-6			
4	7	7	1			
5	9	9	10			
6	5	5	15			
7	0	0	15			
8	-3	3	12			
9	-9	9	3			
10	-4	4	-1			
11	1	1	0	4,73 (*)	0	(***)
12	6	6	6	4,86 (**)	1,23	
13	8	8	14	5,17	2,71	
14	4	4	18	5,05	3,56	
15	1	1	19	4,65	4,09	!! ommezijde
16	-2	2	17	4,39	3,87	
17	-4	4	13	4,35	2,99	
18	-8	8	5	4,72	1,06	
19	-5	5	0	4,75	0	
20	-1	1	-1	4,38	-0,23	

a)

(*) Initial MAD = Sum of cumulative $\lvert e \rvert$ $(1 \to 11) / 11$

$= (8+2+4+7+9+5+0+3+9+4+1)/11 = 4,73$

(**) Subsequent MADs are updated by the formula:

$$MAD_{new} = MAD_{old} + \alpha (\lvert e \rvert_t - MAD_{old})$$

$$MAD_t = MAD_{t-1} + \alpha (\lvert e \rvert_t - MAD_{t-1})$$

$\Rightarrow MAD_{12} = 4,73 + 0,1(6 - 4,73) = 4,86$

$MAD_{13} = 4,86 + 0,1(8 - 4,86) = 5,17$

$MAD_{14} = 5,17 + 0,1(4 - 5,17) = 5,05$

$MAD_{15} = 5,05 + 0,1(1 - 5,05) = 4,65$

$\Rightarrow$ Same formula for the following MADs

(***) $\text{Tracking signal}_t = \dfrac{\Sigma \text{ error}}{MAD_t} \Rightarrow TS_{11} = \dfrac{0}{4,73} = 0$

$TS_{12} = \dfrac{6}{4,86} = 1,23$

!! Assuming the limits of ± 4, the tracking signal in month 15 is outside the limits. The forecast method is exhibiting bias.

b-)

Month	Error	$Error^2$
1	-8	64
2	-2	4
3	4	16
4	7	49
5	9	81
6	5	25
7	0	0
8	-3	9
9	-9	81
10	-4	16
	Sum	345

$$MSE = \frac{\Sigma e^2}{n-1} = \frac{345}{10-1} = 38,33$$

S = standard deviation

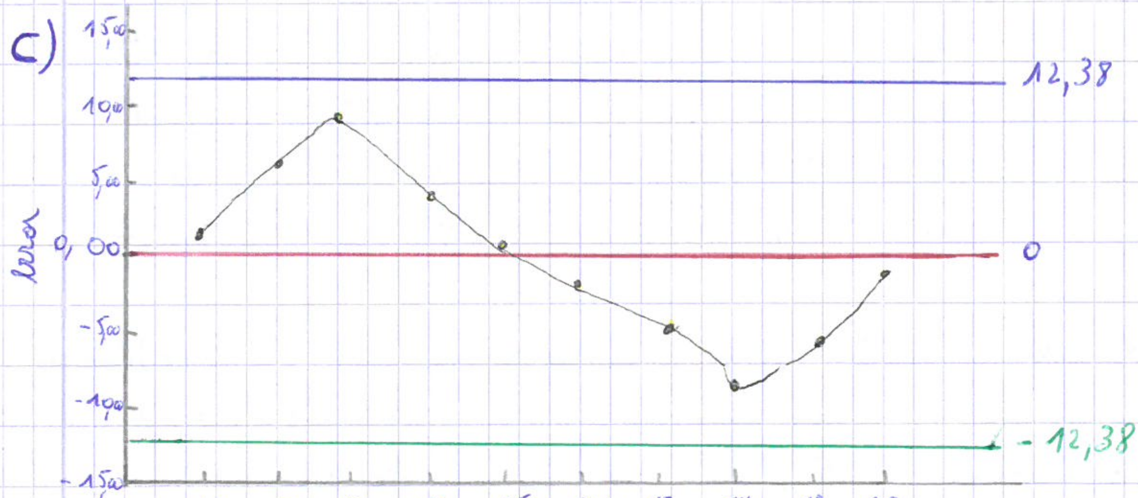
$$s = \sqrt{MSE} = \sqrt{38,33}$$

$\Downarrow$

Control limits $= 0 \pm 2\sqrt{38,33}$

$= 0 \pm 12,38$

c)



The errors may be cyclical, suggesting there might be a cyclical component in demand that is being overlooked in the forecast.

For errors: look at the table: month 11 error = 1
" 12 " = 6
" 13 " = 8
⋮

Les 3 : Strategic capacity planning

[1] *) Machine type — Purchasing cost / machine

Machine type	Purchasing cost / machine
1	\$ 10 000
2	\$ 14 000

*)

Product	Annual Demand (units)	Process time per unit on type 1 (min.)	Process time per unit on type 2 (min)
001	12 000	4	6
002	10 000	9	9
003	18 000	5	3

a) machines operate 8 hours a day, 250 days a year
⇒ how many machines of each type?
⇒ what annual capacity cushion in processing time?

- Each machine is available $250 \times 8 \times 60 = 120\,000$ minutes per year

⇒ Processing requirements using machine type 1:
Product 001 : $12\,000 \cdot 4 = 48\,000$ min
" 002 : $10\,000 \cdot 9 = 90\,000$ min
" 003 : $18\,000 \cdot 5 = 90\,000$ min
} Total = 228 000 min.

Number of machine type 1 needed $= \frac{228\,000}{120\,000} = 1{,}9 = 2$ machines (round up)
Capacity cushion $= 240\,000 - 228\,000 = 12\,000$ minutes

⇒ Processing requirements using machine type 2:
Product 001 : $12000 \cdot 6 = 72\,000$
" 002 : $10\,000 \cdot 9 = 90\,000$
" 003 : $18\,000 \cdot 3 = 54\,000$
} Total = 216 000 minutes

Number of machine type 2 needed $= \frac{216\,000}{120\,000} = 1{,}8 = 2$ machines (round up)

Capacity cushion $= 240\,000 - 216\,000 = 24\,000$ minutes

b) Choice: high / low certainty of demand?

- High uncertainty of demand ⇒ type of machine with the higher capacity cushion (Type 2)

- Low uncertainty of demand ⇒ type of machine with the lower capacity cushion (Type 1)

c) Which type of machine would minimize total costs?

Given: - Operating costs type 1 = $\frac{\$6}{hour}$

- " " type 2 = $\frac{\$5}{hour}$

Machine type 1

- Purchasing cost = 2 machines × $10 000 / machine = $20 000
- Total operating time = 228 000 minutes = 3800 hours
- " " cost = 3800 hours × $\frac{\$6}{hour}$ = $22800
- Total cost = $20 000 + $22800 = $42800

Machine type 2

- Purchasing cost = 2 machines × $14 000 / machine = $28 000
- Total operating time = 216 000 minutes = 3600 hours
- " " cost = 3600 hours × $\frac{\$5}{hour}$ = $18 000
- Total cost = $28000 + $18 000 = $46 000

⇒ Conclusion: machine type 1 would minimize total cost.

2 *) - 1 line : fixed cost of $\frac{\$6000}{month}$ 2 lines : fixed cost of $\frac{\$10500}{month}$

- each line : 15 cars / hour
- variable cost / car = \$3
- revenue / car = \$5,95
- Avarage demand : between 14 and 18 / hour
- Car wash is open 300 hours / month

<u>Break even quantity per hour</u>

One line : $\frac{\text{Fixed cost}}{\text{Revenue - variable cost}} = \frac{FC}{R - v} = \frac{\$20}{\$5{,}95 - \$3{,}00} = 6{,}78$ cars

Two lines : $\frac{FC}{R - v} = \frac{\$35}{\$5{,}95 - \$3{,}00} = 11{,}86$ cars

$FC = \frac{\text{Total fixed cost / month}}{\text{Operating hours}}$

⇒ If demand avarages between 14 - 18 cars an hour, both options would atleast break even.

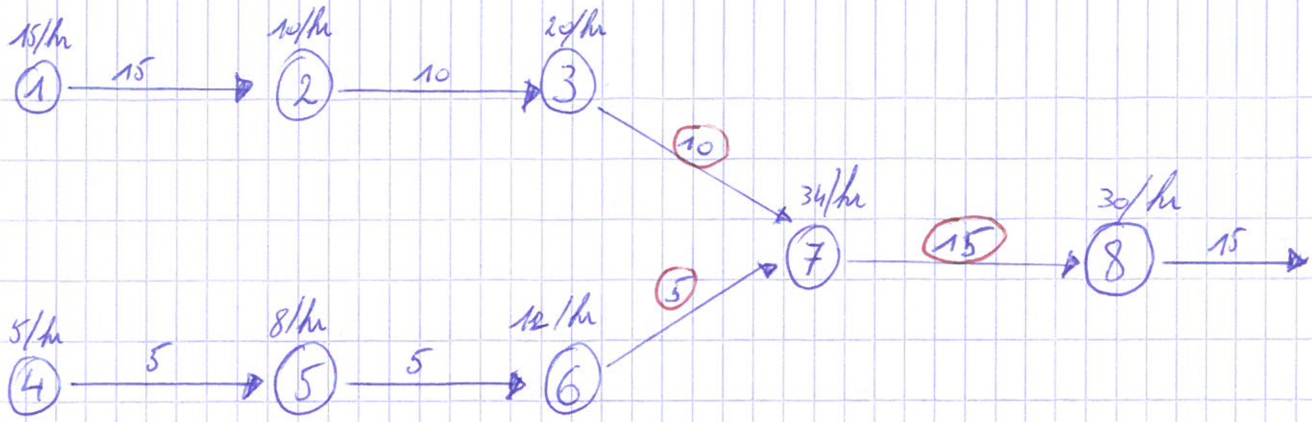
(*) Each line would be able to process 15 cars per hour !!

Volume	No. of lines used	Net profit per hour
14	1	14 . (5,95 - 3) - 20 = 21,30
15	1	15 (5,95 - 3) - 20 = 24,25
16	1	15 ~~16~~ (5,95 - 3) - 20 = 24,25
17	1	(*) 15 ~~17~~ (5,95 - 3) - 20 = 24,25
18	1	15 ~~18~~ (5,95 - 3) - 20 = 24,25
14	2	14 (5,95 - 3) - 35 = 6,30
15	2	15 (5,95 - 3) - 35 = 9,25
16	2	16 (5,95 - 3) - 35 = 12,20
17	2	17 (5,95 - 3) - 35 = 15,15
18	2	18 (5,95 - 3) - 35 = 18,10

⇒ Choose 1 line. Net profit per hour is always higher for the given demand range of 14 - 18 cars per hour.

3

a)

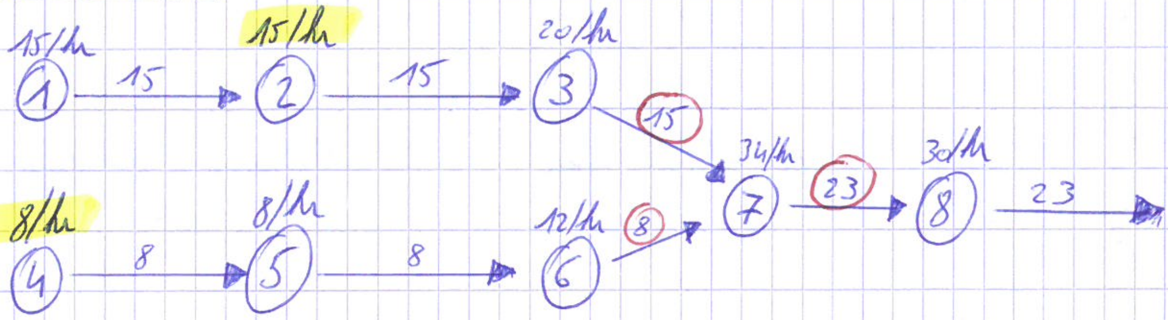


Capacity of the system : 15/hr

b) What will be the capacity of the system if you increase the capacity of 2 operations.

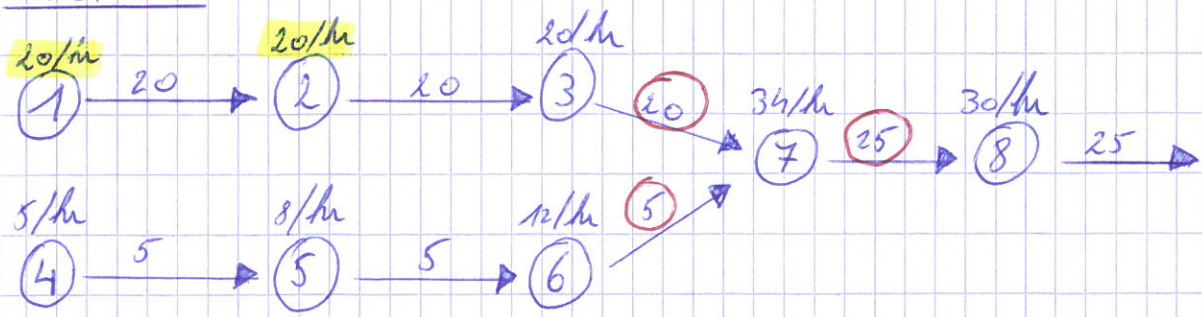
- Which ones + how much additional capacity?

Choice 1



Capacity of new system : 23/hr

Choice 2



⇒ Capacity of new system : 25/hr ⇒ Choice 2 is better

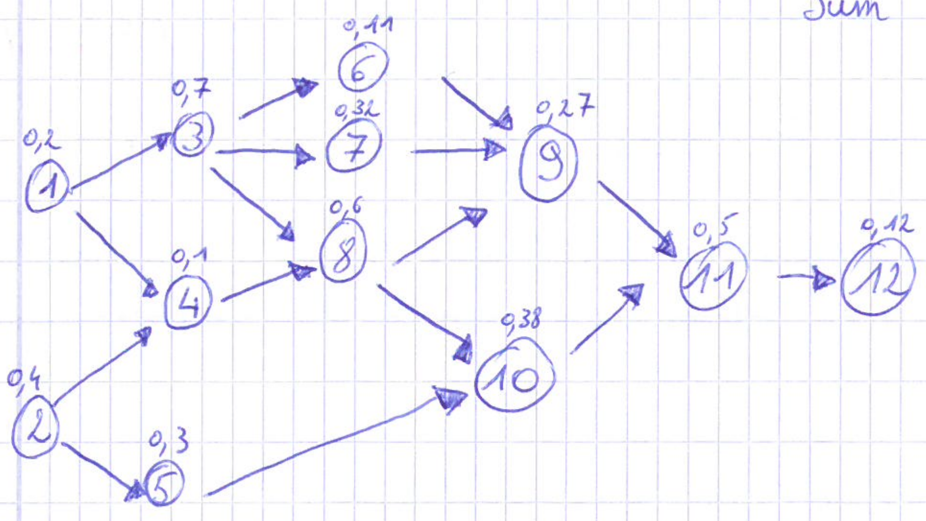
Les 4: Process selection and facility layout

$\boxed{1}$ Exercise line balancing

⇒ Precedence graph + balance a line of following tasks

⇒ Target production: $\frac{60 \text{ pieces}}{\text{hour}}$

Task	T_i (min)	Predecessors
1	0,2	/
2	0,4	/
3	0,7	1
4	0,1	1;2
5	0,3	2
6	0,11	3
7	0,32	3
8	0,6	3;4
9	0,27	6;7;8
10	0,38	5;8
11	0,5	9;10
12	0,12	11
Sum	4,00	



Positional weight$_i$ (PW_i) = Σ time of following tasks (including i!)

⇒ e.g: $PW_1 = 0,2+0,7+0,1+0,6+0,11+0,32+0,27+0,38+0,5+0,12$
$= 3,3$

$PW_2 = 0,4+0,1+0,3+0,6+0,27+0,38+0,5+0,12$
$= 2,67$

Number of Following tasks (#FT) = self explanatory

e.g For task 1 : 3, 4, 6, 7, 8, 9, 10, 11, 12 = 9
e.g " " 2 : 4, 5, 8, 9, 10, 11, 12 = 7

⇓

Task	PW	FT
1	3,30	9
2	2,67	7
3	3,00	7
4	1,97	5
5	1,30	3
6	1,00	3
7	1,21	3
8	1,87	4
9	0,89	2
10	1,00	2
11	0,62	1
12	0,12	0

Cycle time = $\frac{60 \text{ min}}{60 \text{ pieces}} = 1 \frac{\text{min}}{\text{pc}}$

Sum of all tasks = 4,0

Tie breaks ! (rule: use the lowest task number first)
(*)

both have PW = 1,00

*) <u>Balancing: positional weight</u>

Tasks ranked by PW :	1	3	2	4	8	5	7	6	10	9	11	12
time	0,2	0,7	0,4	0,1	0,6	0,3	0,32	0,11	0,38	0,27	0,5	0,12

Task time can't exceed 1 min !

You can only do 1 or 2 to start

1) Positional weight

This can't exceed 1 min!

Eligible tasks	Assignment (total time assigned)
~~1~~, 2	1 (0,2)
2, ~~3~~	1, 3 (0,9)
~~2~~, 6, 7	1,3 (0,9) and 2 (0,4)
6, 7, ~~4~~, 5	1,3 (0,9) and 2, 4 (0,5)
6, 7, 5, ~~8~~	1,3 (0,9) and 2, 4 (0,5) and 8 (0,6)
6, 7, ~~5~~	1,3 (0,9) and 2, 4, 5 (0,8) and 8 (0,6)
6, ~~7~~, 10	1,3 (0,9) and 2, 4, 5 (0,8) and 8, 7 (0,92)
~~6~~, 10	1,3 (0,9) and 2,4,5,6 (0,91) and 8,7 (0,92)
~~10~~, 9	1,3 (0,9) and 2,4,5,6 (0,91) and 8,7 (0,92) and 10 (0,38)
~~9~~	1,3 (0,9) / 2,4,5,6 (0,91) / 8,7 (0,92) / 10, 9 (0,65)
~~11~~	1,3 (0,9) / 2,4,5,6 (0,91) / 8,7 (0,92) / 10,9 (0,65) / 11 (0,5)
~~12~~	1,3 (0,9) / 2,4,5,6 (0,91) / 8,7 (0,92) / 10,9 (0,65) / 11, 12 (0,62)

After 1 is done, you can only do 2 or 3

* After 3 is done, you can do tasks 2, 6 or 7 ⇒ which one has the highest PW?

Chose the option that has the highest PW

Add the amount of time to a group so it won't exceed 1. If it would be higher than 1 ⇒ make a new group.

Evaluation

Balance loss : $\frac{5-4}{5} = 20\%$ (Can only use 4 workstations, but you have 5)

Efficiency : $1 - 20\% = 80\%$

Min. number of workstations : $\frac{4}{1} = \frac{\text{sum of tasks (time)}}{\text{cycle time}} = 4$

Min. balance loss $= 0\%$

Max. efficiency $= 100\%$

Smoothness index of 0 = perfect balance

- Smoothness index = shows the relative smoothness of a given line balance

$$= \sqrt{\sum_{i=1}^{n} (\text{maximum station time} - \text{station time}_i)^2}$$

$$= \sqrt{0{,}02^2 + 0{,}01^2 + 0^2 + 0{,}27^2 + 0{,}30^2} = 0{,}404$$

Tie breaks! Same amount of FTs $\Rightarrow$ use lowest task number first

2) Balancing: most following tasks

Tasks ranked by #FT:

1	2	3*	4	8	5*	6*	7*	9*	10*	11	12
0,2	0,4	0,7	0,1	0,6	0,3	0,11	0,32	0,27	0,38	0,5	0,12

Eligible tasks	assignment (total time assigned) can't exceed 1
~~1~~, 2	1 (0,2)
~~2~~, 3	1, 2 (0,6)
~~3~~, 4, 5	1, 2 (0,6) / 3 (0,7)
~~4~~, 5, 6, 7	1, 2, 4 (0,7) / 3 (0,7)
5, 6, 7, ~~8~~	1, 2, 4 (0,7) / 3 (0,7) / 8 (0,6)
~~5~~, 6, 7	1, 2, 4, 5 (1) / 3 (0,7) / 8 (0,6)
~~6~~, 7, 10	1, 2, 4, 5 (1) / 3, 6 (0,81) / 8 (0,6)
~~7~~, 10	1, 2, 4, 5 (1) / 3, 6 (0,81) / 8, 7 (0,92)
10, ~~9~~	1, 2, 4, 5 (1) / 3, 6 (0,81) / 8, 7 (0,92) / 9 (0,27)
~~10~~	1, 2, 4, 5 (1) / 3, 6 (0,81) / 8, 7 (0,92) / 9, 10 (0,65)
~~11~~	1, 2, 4, 5 (1) / 3, 6 (0,81) / 8, 7 (0,92) / 9, 10 (0,65) / 11 (0,5)
~~12~~	1, 2, 4, 5 (1) / 3, 6 (0,81) / 8, 7 (0,92) / 9, 10 (0,65) / 11, 12 (0,62)

Evaluation

- Balance loss: $\frac{5-4}{5} = 20\%$
- Efficiency $= 1 - 20\% = 80\%$
- Min. no of workstations $= \frac{4}{1} = 4$
- Min. balance loss $= 0\%$ $\frac{4-4}{4} = \frac{0}{0} = 0$
- Max. efficiency $= 100\%$

Smoothness index $= \sqrt{\sum_{i=1}^{n} (\text{max station time} - \text{station time}_i)^2}$

$= \sqrt{0^2 + 0{,}19^2 + 0{,}08^2 + 0{,}35^2 + 0{,}38^2} = 0{,}556$

The first solution (PW) has ~~a~~ a lower smoothness index
$\Rightarrow$ first solution seems slightly better.

2 A: absolutely necessary
E: especially important
I: important
O: ordinary importance
U: unimportant
X: undesireable

3x3 format, department 5: lower left corner.

A links	X links	E links	I links
1 - 3	1 - 2	1 - 3	2 - 4
1 - 7	1 - 6	1 - 9	
1 - 8	2 - 3	2 - 9	
2 - 5	3 - 4	3 - 7	
2 - 6	3 - 6	4 - 8	
2 - 7	3 - 8	6 - 7	
3 - 9	4 - 5		
4 - 6	4 - 9		
4 - 7	5 - 6		
5 - 7	5 - 8		
5 - 9	6 - 9		
7 - 8	8 - 9		
7 - 9			

Looking at the A links, we can see that Department 7 appears most frequently followed by Departments 1, 2, 5 & 9, and then Departments 3, 4, 6 & 8.

	# of A links
1	3
2	3
3	2
4	2
5	3
6	2
7	6
8	2
9	3

7 = good candidate for central location
⇒ satisfy remaining A & X conditions
⇒ trial & error to move departments to satisfy E & I conditions

Layout

3	1	8
9	7	4
5	2	6

3 *) Develop suitable layout that minimizes transportation costs.
*) Compute the total cost

First: assign work center pairs based on ranking them by number of trips between them.

No. of trips between	Loads per day	Order of assignment
1-5	370	1
2-3	360	2
3-4	350	3
3-8	200	4
4-5	190	5 (tie)
4-8	180	5 (tie)
1-6	135	6
1-7	125	7
1-4	120	8 (tie)
2-8	120	8 (tie)
2-6	115	9
3-5	110	10
1-4	90	11
4-6	70	12
4-7	50	13
6-7	50	13
2-7	45	14
2-5	40	15
3-6	40	15
5-7	40	15
3-7	20	16
6-8	20	16
7-8	20	16
1-2	10	17
5-6	10	17
5-8	10	17
1-3	5	18
1-8	0	19

⇒ A reasonable (intuitive) set of assignments is:

A #1	B #5	
C #7	D #4	E #3
F #6	G #2	H #8

Given (**)

- The distance (in meters) between work centers for this option (**)

	From	To	A 1	G 2	E 3	D 4	B 5	F 6	C 7	H 8
(A)	1			100	120	60	40	80	40	110
(G)	2				50	40	120	40	70	40
(E)	3					40	60	90	85	40
(D)	4						40	50	45	45
(B)	5							140	60	130
(F)	6								40	60
(C)	7									90
(H)	8									

- Then, for each work center pair, we must multiply # of trips x distance x $1.

From	To	1	2	3	4	5	6	7	8
1			1000	600	5400	14800 (*)	10800	5000	0
2				18 000 (*)	4800	4800	4600	3150	4800
3					14000	6600	3600	1700	8000
4						7600	3500	2250	8550 (*)
5							1400	2400	1300
6								2000	1200
7									1800
8									

(*) = 370 x 40 x 1 = 14800

(*) = 190 x 45 x 1 = 8550

(*) = 360 x 50 x 1 = 18 000

- This set of assignments has a total cost of $ 143 650 per day
- Slight variations would also be reasonable. They can be compared by calculating total costs

4 Exercise layout : estimate distance separating departments

The coordinates of centers could be determined at:

	x	y
A	10	70
B	55	70
C	80	50
D	65	0
E	0	15

To

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

$AB = 45$ (see figure)

$AD = \sqrt{55^2 + 70^2} = 89$

$BC = \sqrt{25^2 + 20^2} = 32$

$CD = \sqrt{50^2 + 15^2} = 52$

$DE = \sqrt{15^2 + 65^2} = 67$

$EA = \sqrt{55^2 + 10^2} = 56$

With : $A^2 + B^2 = C^2$

$\Rightarrow C = \sqrt{A^2 + B^2}$

- distance between A & D horizontally

= |← 20 →| (top left) |← 25 →| (bottom right)

↓

total distance = 100

$100 - 20 - 25 = 55$

- distance between A & D vertically

= 20 (top left)

→ total distance = 100

$\Rightarrow 100 - 20 - 10 = 70$

10 (right bottom)