PLANT LAYOUT

Education and Culture DG
Lifelong Learning Programme

PLANT LAYOUT

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LLA

LEAN LEARNING ACADEMY

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Course content

1. Layout: definition
2. Lean plant layout
3. Layout types
4. Layout optimisation
5. Examples
6. References

1. Layout: definition

Layout design is about finding the best position for

- machines (in production settings) or
- desks (in office settings) or
- service centers (in e.g. hospitals, department stores,…)

in order to facilitate flow of information, materials and people between areas.

2. Lean plant layout

2.1. A lean layout supports the organisation's strategy

Organisation's strategy	Priority	Layout requirements
Differentiation	High process flexibility, specific equipment, short setup times	Specialised cells
Low cost	Efficient processes, low cost of transportation and material handling	Product based layout
Quick respons	Rapid development, short setup times, short customer lead times	Short product routings

2. Lean plant layout

2.2. A lean plant layout takes into account

- Space utilisation
- Flow of information, materials and people
- Working conditions (safety, social aspect,…)
- Customer/client interaction
- Production flexibility
- Costs of material handling, space,…

2. Lean plant layout

2.3. Before designing a lean plant layout, determine

- Necessary material handling equipment
- Space requirements
- Required capacity
- Information flow
- Cost of moving between work areas

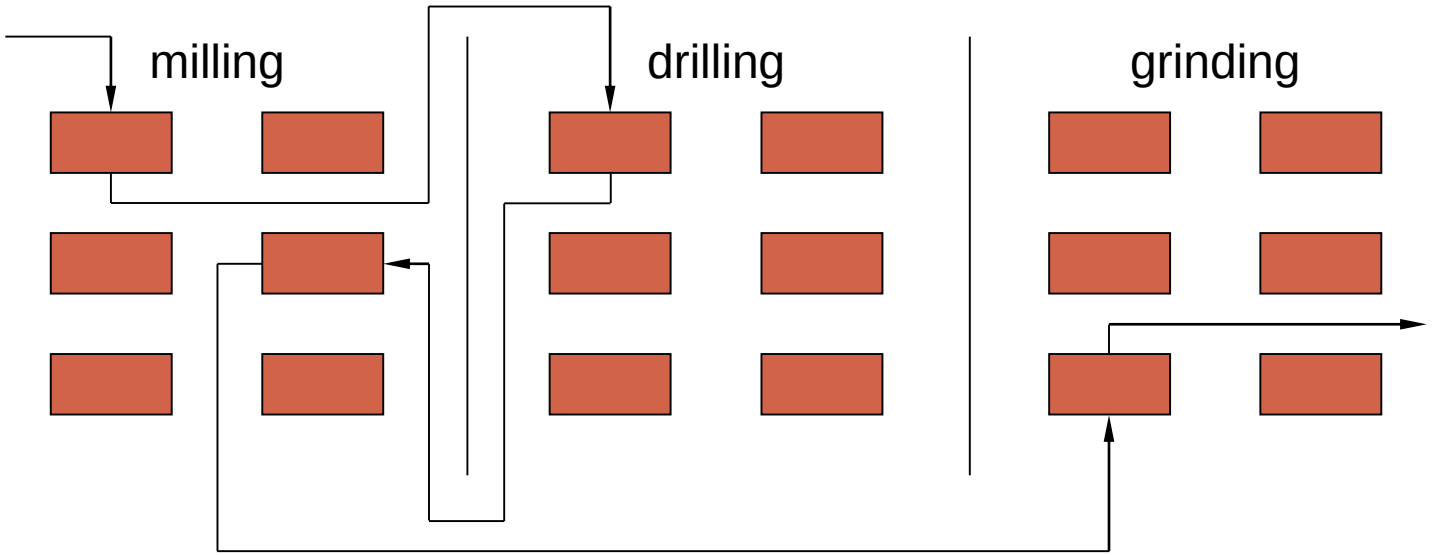
2. Lean plant layout

2.4. Keep in mind that

- a layout determines waste for many years.
- having nearby suppliers saves transportation costs.
- supplying directly to the workstations through multiple external doors, reduces transportation costs.
- designing a layout is a 3D-problem: consider deliveries from below or above.
- design and engineering areas should be close to manufacturing.
- production control should be in the middle of the plant floor.

3.1. Proces-oriented layout or job shop:

= technically identical machines/processes are grouped together in a workcenter



3. Layout types

3.1. Proces-oriented layout or job shop:

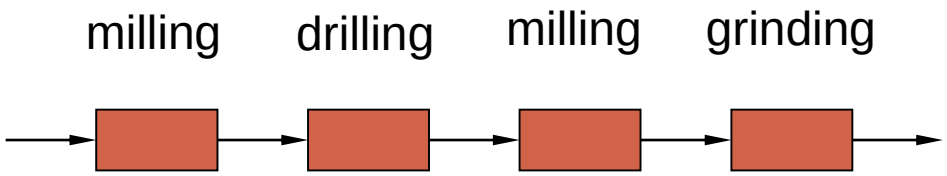
Best for **low volume** production

Layout KPI's	Job shop	
Amount of work in process	high	
Throughput lead time	high	
Traveling distance	high	
Flexibility	high	
Production continuity assurance	high	
Work centre occupation	high	

Layout optimisation problem: facility location

3.2. Product-oriented layout or flow shop:

= machines/processes are put in a product routing sequence



3.2. Product-oriented layout or flow shop:

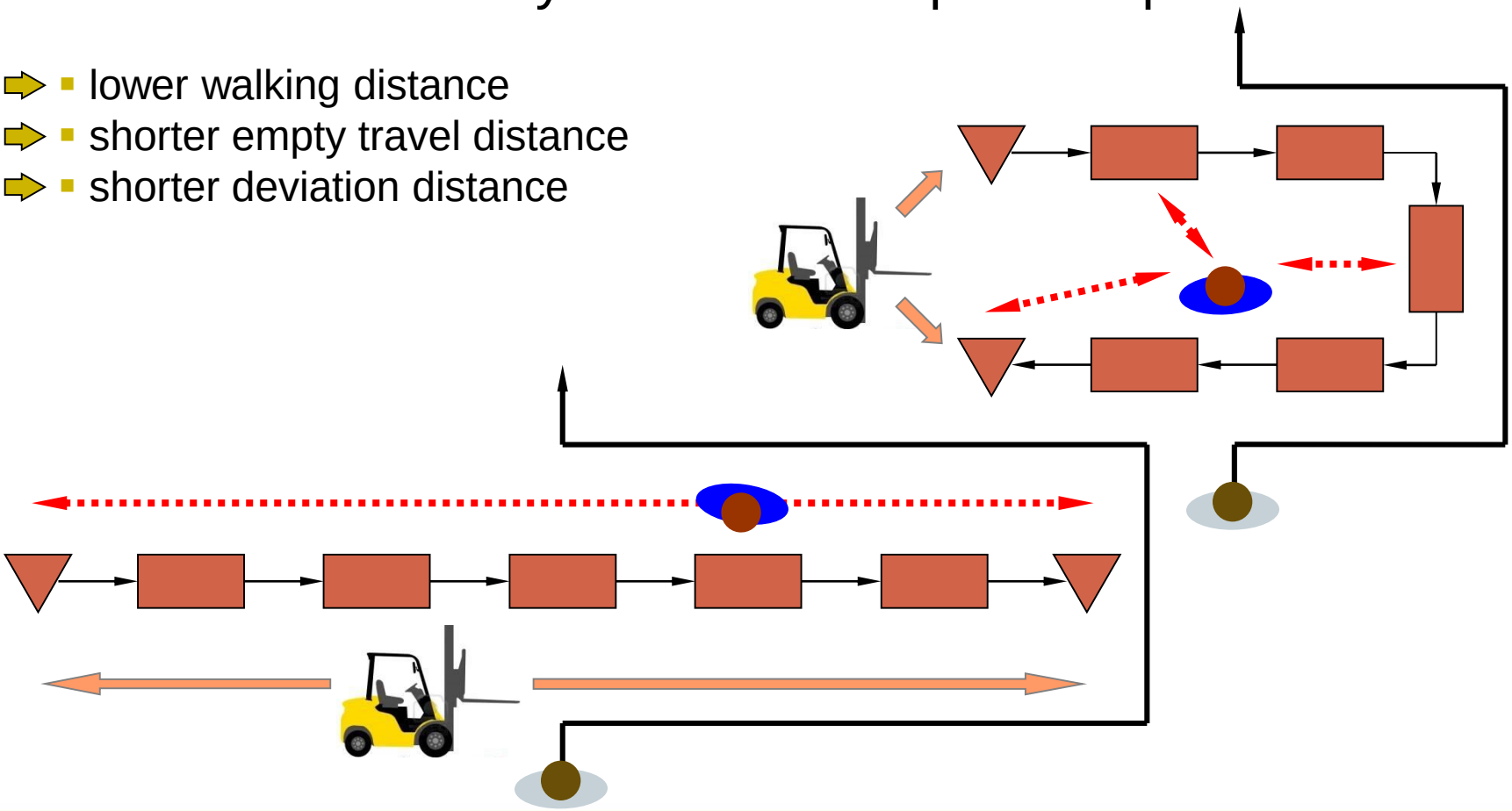
Best for **high volume** production

Layout KPI's	Flow shop	
Amount of work in process	low	
Throughput lead time	low	
Traveling distance	low	
Flexibility	low	
Production continuity assurance	low	
Work centre occupation	low	

Layout optimisation problem: line balancing

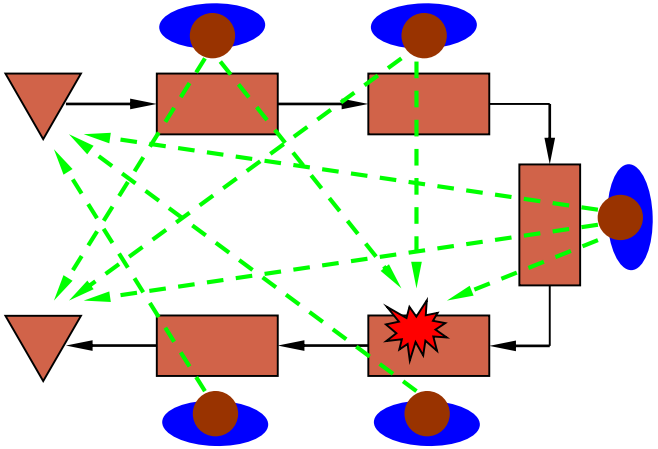
3.2. Product-oriented layout or flow shop: U-shaped lines

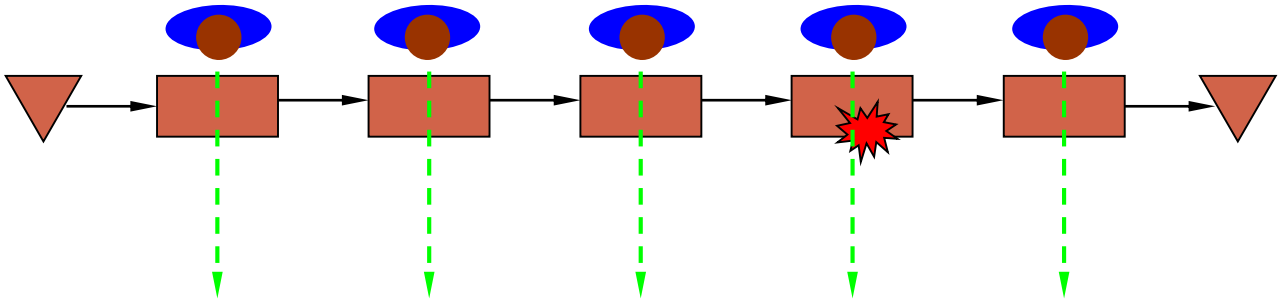
- lower walking distance
- shorter empty travel distance
- shorter deviation distance



3.2. Product-oriented layout or flow shop: U-shaped lines

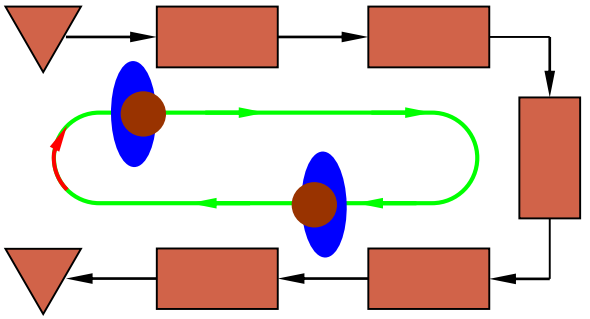
- easier communication
- better view on inventory, flow, problems,…
- easier social contacts

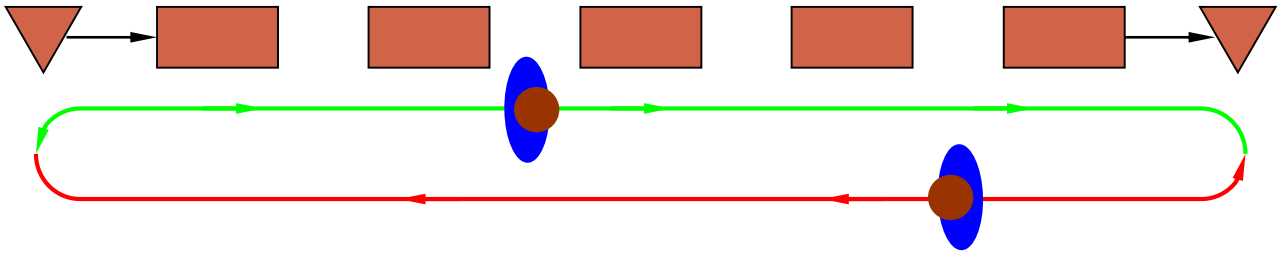




3.2. Product-oriented layout or flow shop: U-shaped lines

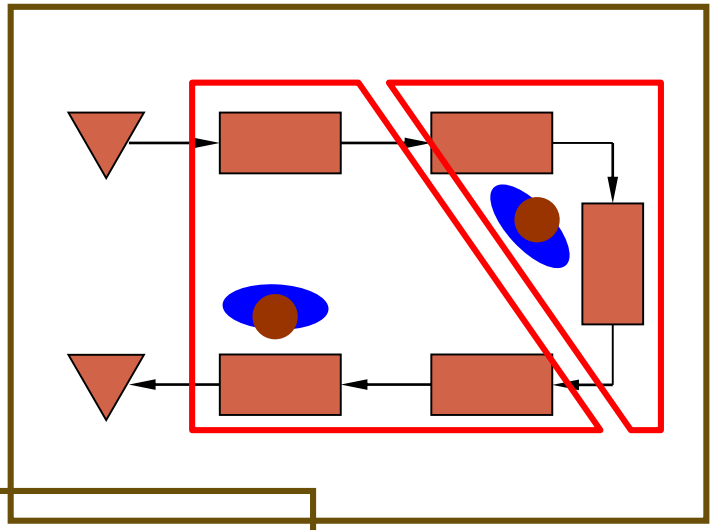
- more efficient ‘rabbit chase’ production

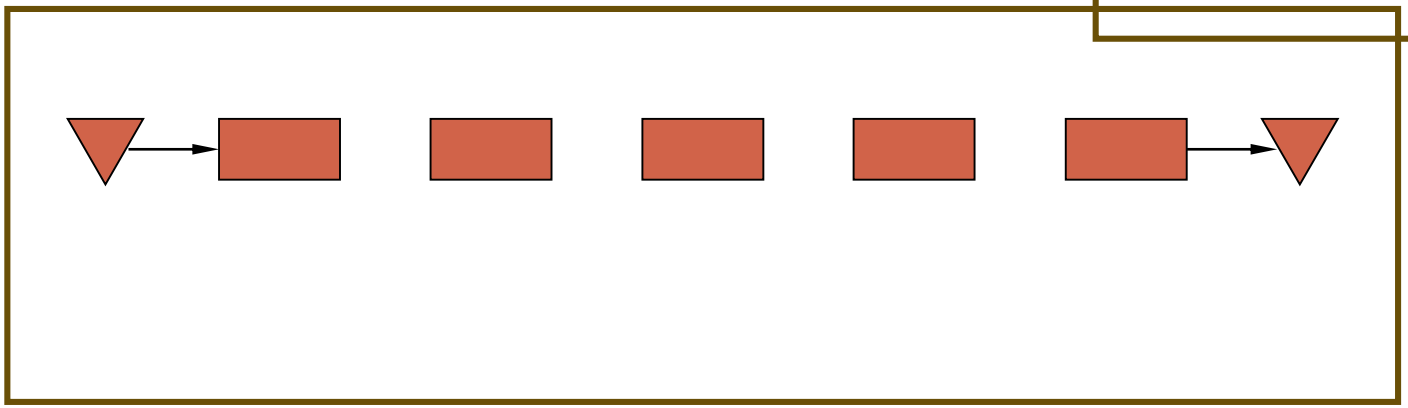




3.2. Product-oriented layout or flow shop: U-shaped lines

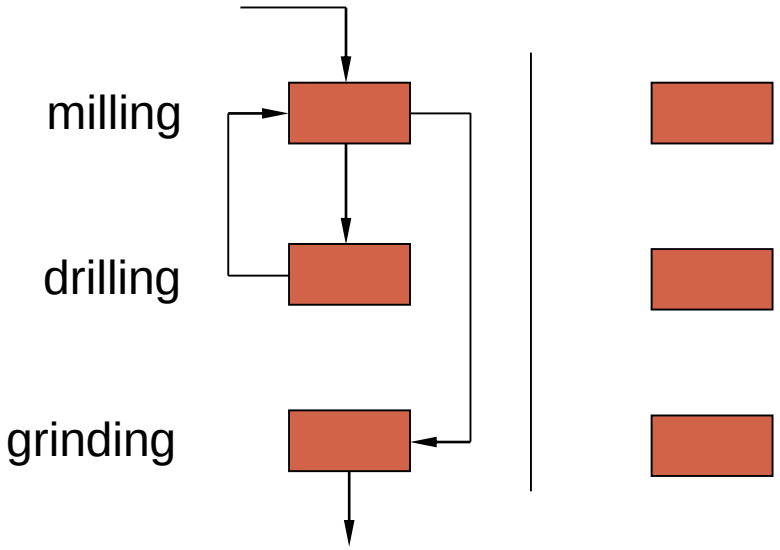
- more possibilities to balance the line
- takes up less floor space





3.3. Cell layout or work cell:

= machines/processes are grouped into cells in which families of related products/services are processed



3.3. Cell layout or work cell:

Layout KPI's	Work cell	
Amount of work in process	rather low	
Throughput lead time	rather low	
Traveling distance	rather low	
Flexibility	rather low	
Production continuity assurance	rather low	
Work centre occupation	rather low	

Layout optimisation problem: group technology

3.4. Other types of layout: (that will not be considered further)

- Fixed position layout or project layout:

  = a layout in which a product is processed at a fixed position and all resources (machines, materials, people) are brought to that location.

- Office layout

  = a layout in which workers, equipment, desks and spaces are positioned to allow a fast and easy information flow.

- Warehouse layout

  = a layout that provides efficient space utilisation and easy material handling.

4. Layout optimisation

4.1. Job shop optimisation: facility location

based on

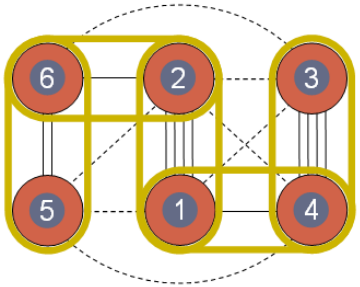
Quantitative data

Input:

FROM \ TO	1 observation room	2 nursery	3 X-ray	4 laboratory	5 surgery room	6 intensive care
1 Observ.	0	80	10	20	15	0
2 Nursery	95	0	5	10	0	0
3 X-ray	0	15	0	100	0	8
4 Laborat.	20	0	90	0	25	0
5 Surgery	0	20	0	0	0	40
6 Intensive	0	35	0	0	60	0

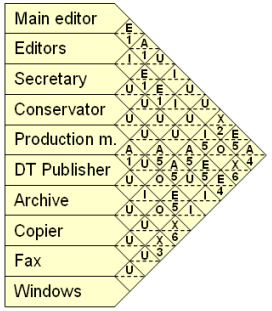
From-to table

Output:

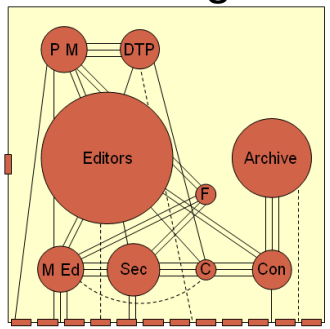


CRAFT ← Contact intensity graph

Qualitative data



Relation diagramme



Contact intensity graph

4.2. Flow shop optimisation: line balancing

Step 1: Determine process precedence relations

Step 2: Draw process precedence diagramme

Step 3: Calculate cycle time

Step 4: Calculate minimum number of workstations

Step 5: Assign tasks to workstations

Step 6: Calculate assembly line efficiency

4.2. Flow shop optimisation: line balancing

Step 5: Solving the task assignment problem using

- Heuristics (do not guarantee the optimal solution)

  From the available tasks, choose the task:

  - with the longest time
  - with the largest number of following tasks
  - for which the sum of the times for each following task is longest
  - with the shortest task time
  - with the least number of subsequent tasks

- Optimisation techniques (provide the optimal solution)
  - Integer programming
  - Dynamic programming
  - Branch and bound

4.3. Work cell optimisation: group technology

This technique creates product families which each need a limited number of different machines

Step 1: Draw a process steps matrix

- with m rows representing m machines
- with n columns referring to n products
- a_{ij} = 1 if product j needs machine i and a_{ij} = 0 if not

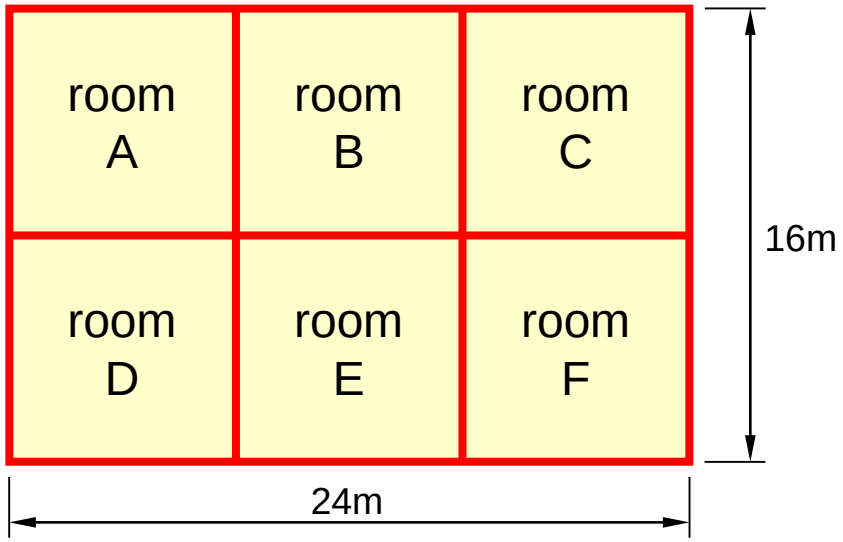
Step 2: Use a technique to create product families

- heuristics:
  - Rank Order Clustering (ROC) of King (1980)
  - Direct Clustering Analysis (DCA) of Chan and Milner (1982)
  - Cluster Identification Algoritm (CIA) of Kusiak and Chow (1987)

5.1. Example: job shop layout design:

Objective:

Allocate hospital facilities (1, 2, 3, 4, 5, 6) to rooms (A, B, C, D, E, F) measuring 8m x 8m in such a way that the total weekly distance (**quantitative** criterion!) patients have to be moved is minimised.



5. Examples

5.1. Example: job shop layout design:

Step 1: Estimate the number of patient movements between hospital facilities and put them in a from-to table

		1	2	3	4	5	6
	TO / FROM	observation room	nursery	X-ray	laboratory	operating room	intensive care
1	Observ.	0	80	10	20	15	0
2	Nursery	95	0	5	10	0	0
3	X-ray	0	15	0	100	0	8
4	Laborat.	20	0	90	0	25	0
5	Operating	0	20	0	0	0	40
6	Intensive	0	35	0	0	60	0

5.1. Example: job shop layout design:

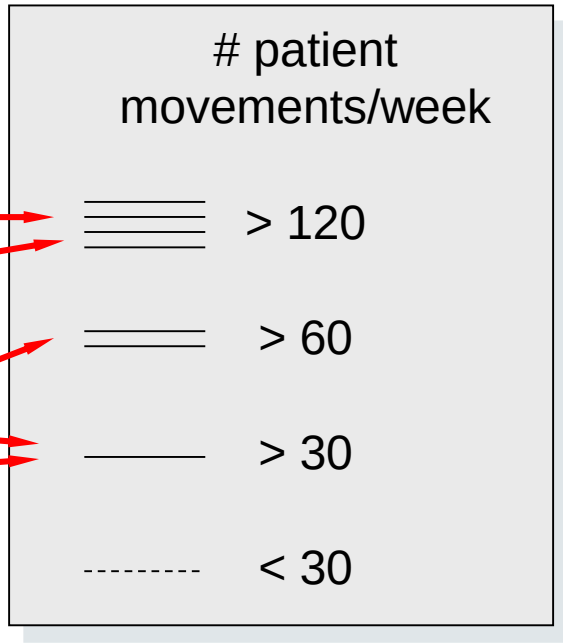
Step 2: Turn the from-to table into a table representing movements between facilities

	AND BETWEEN	1 observation room	2 nursery	3 X-ray	4 laboratory	5 surgery room	6 intensive care
1	Observ.	0	0	0	0	0	0
2	Nursery	175	0	0	0	0	0
3	X-ray	10	20	0	0	0	0
4	Laborat.	40	10	190	0	0	0
5	Surgery	15	20	0	25	0	0
6	Intensive	0	35	8	0	100	0

5.1. Example: job shop layout design:

Step 3: Group all numbers into classes and for each class determine the number of lines for drawing the contact intensity graph

betw	1	2	3	4	5	6
1	0	0	0	0	0	0
2	175	0	0	0	0	0
3	10	20	0	0	0	0
4	40	10	190	0	0	0
5	15	20	0	25	0	0
6	0	35	8	0	100	0



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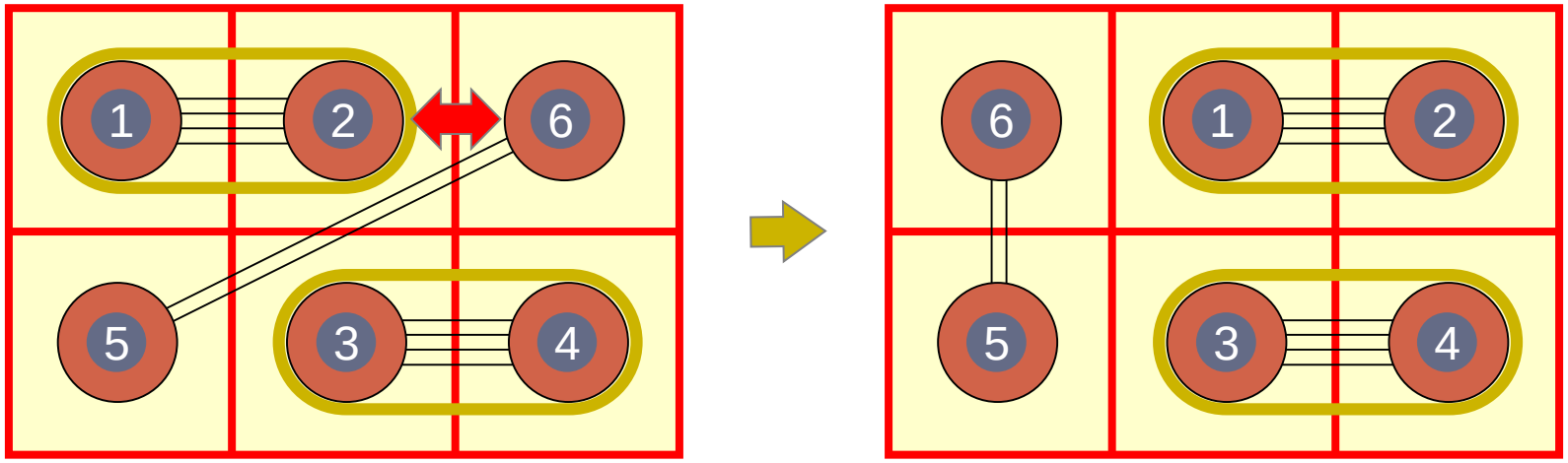
5.1. Example: job shop layout design:

Step 4: Draw the contact intensity graph starting with the highest contact intensities and rearrange the facility locations as soon as you discover improvement opportunities.



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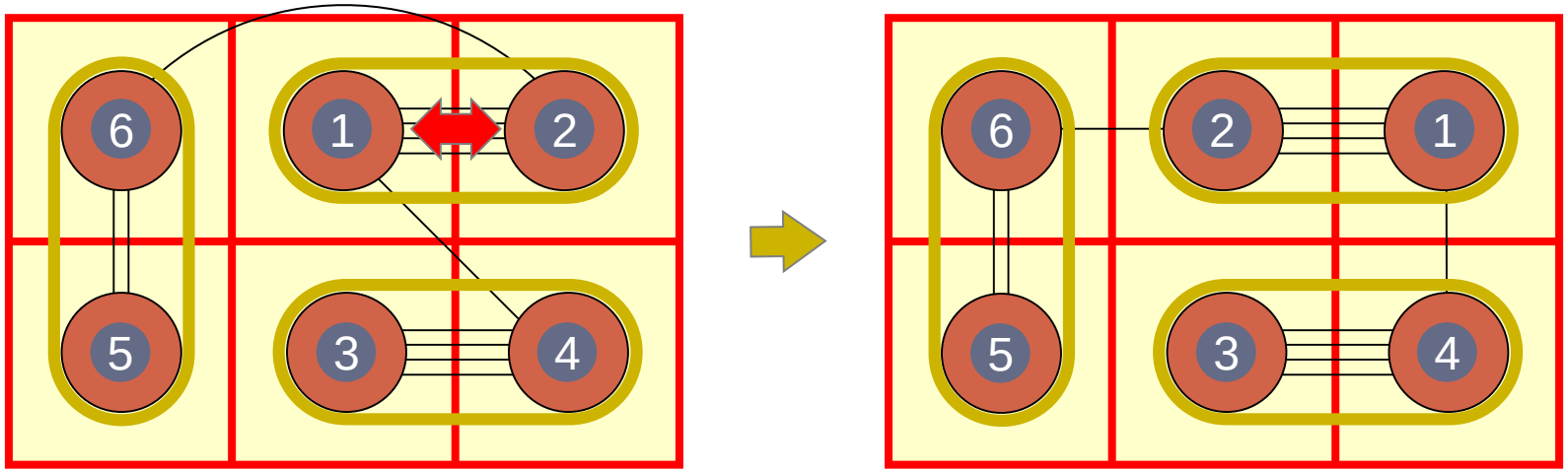

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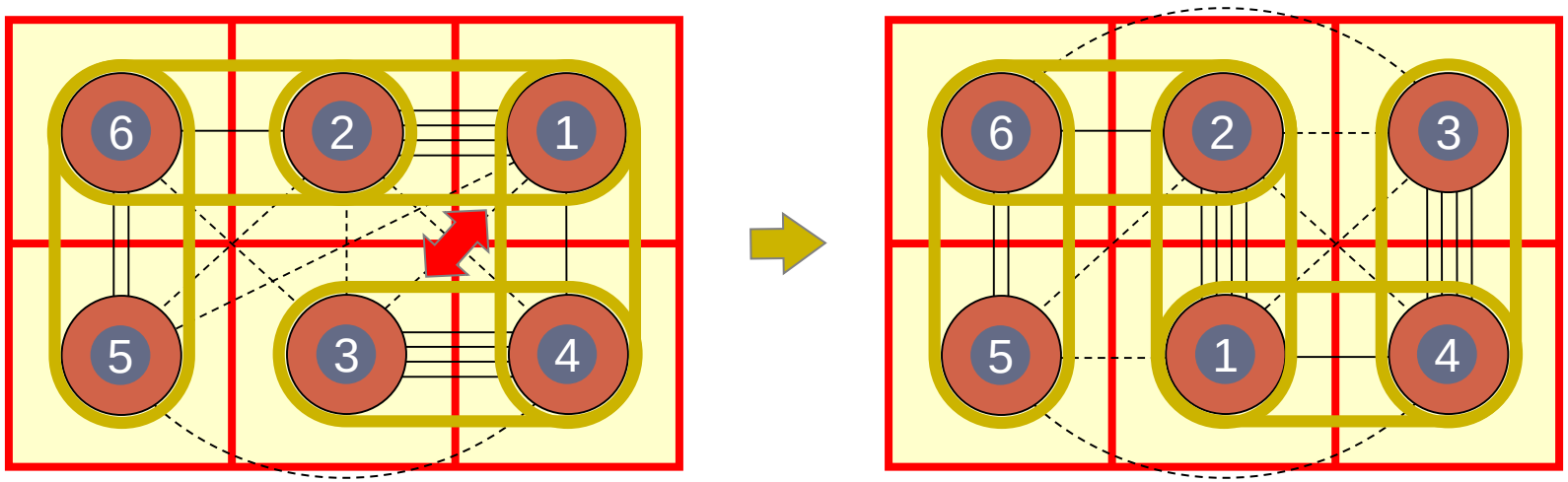
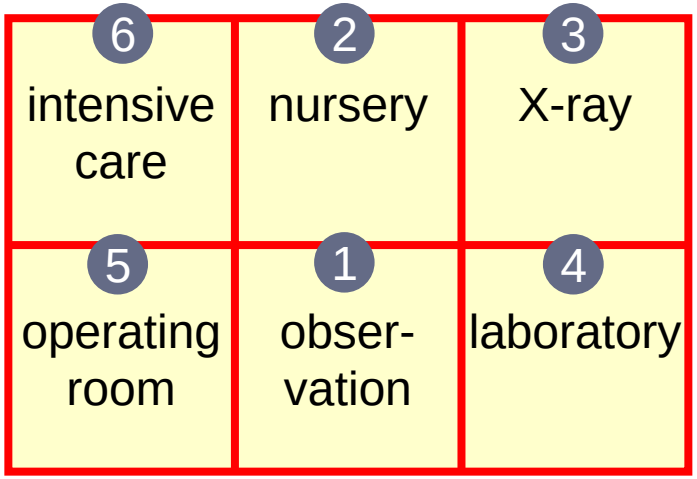


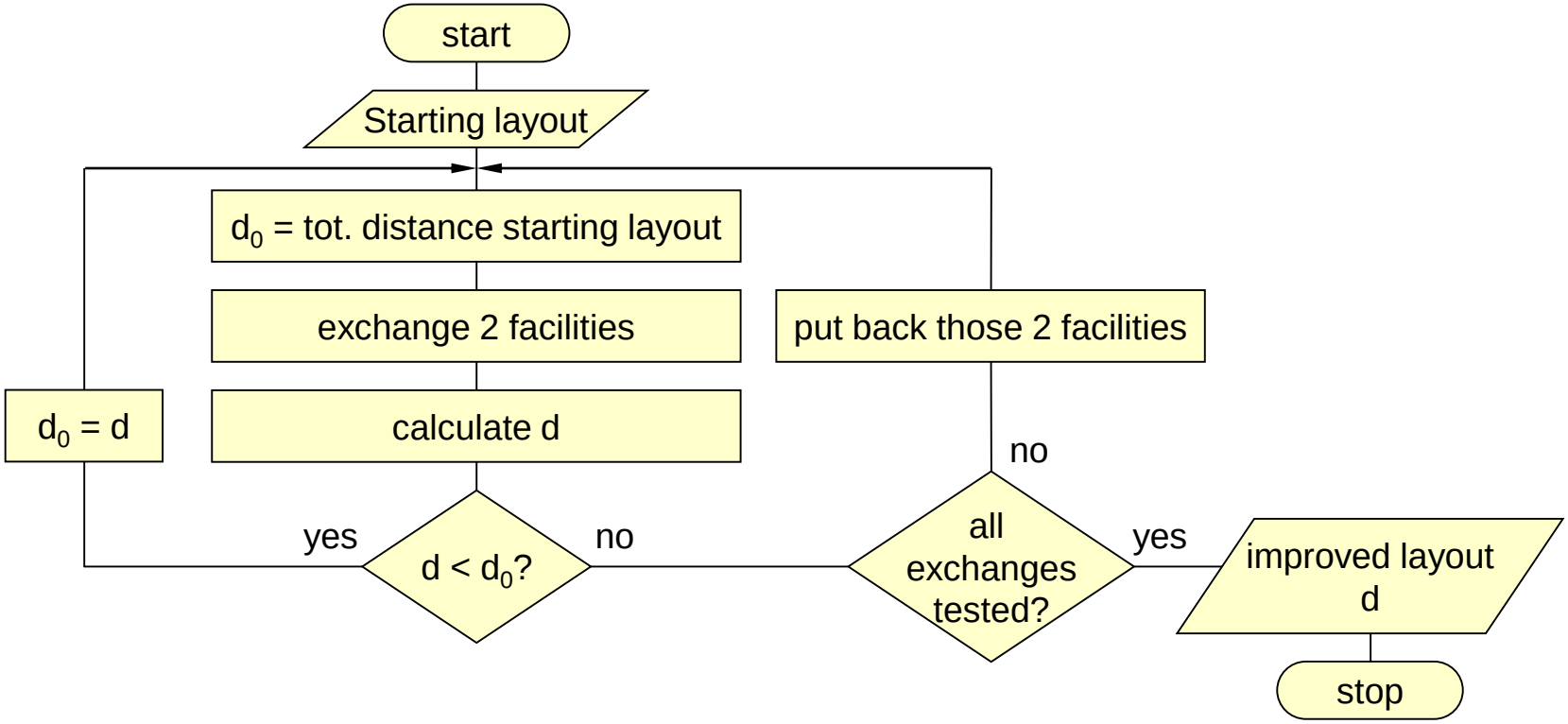
5.1. Example: job shop layout design:

Step 5: Replace facility numbers by facility names



5.1. Example: job shop layout design:

Step 6: Use CRAFT to try to improve this layout



5.1. Example: job shop layout design:

Step 6: Use CRAFT to try to improve this layout

	Tot. distance **5760 m**	1 observation room	2 nursery	3 X-ray	4 laboratory	5 surgery room	6 intensive care
1	Observ.	0	0	0	0	0	0
2	Nursery	175 x 8m	0	0	0	0	0
3	X-ray	10 x 16m	20 x 8m	0	0	0	8
4	Laborat.	40 x 8m	10 x 16m	190 x 8m	0	0	0
5	Surgery	15 x 8m	20 x 16m	0 x 24m	25 x 16m	0	0
6	Intensive	0 x 16m	35 x 8m	8 x 16m	0 x 24m	100 x 8m	0

Distance measured between room centres through perpendicular paths!

5.1. Example: job shop layout design:

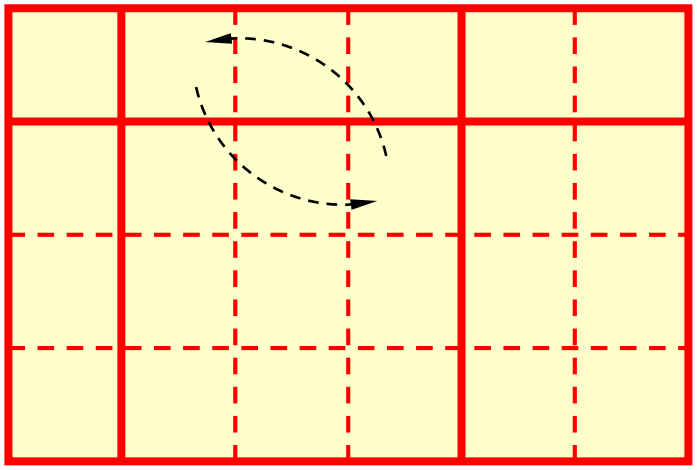
Step 6: Use CRAFT to try to improve this layout

CRAFT could not improve this layout!

Nr.	A	B	C	D	E	F	Tot. distance	Nr.	A	B	C	D	E	F	Tot. distance
0	6	2	3	5	1	4	5760m	8	6	1	3	5	2	4	6328m
1	2	6	3	5	1	4	7984m	9	6	4	3	5	1	2	6328m
2	3	2	6	5	1	4	10408m	10	6	2	5	3	1	4	7864m
3	5	2	3	6	1	4	6272m	11	6	2	1	5	3	4	6008m
4	1	2	3	5	6	4	6408m	12	6	2	4	5	1	3	6352m
5	4	2	3	5	1	6	8344m	13	6	2	3	1	5	4	8008m
6	6	3	2	5	1	4	8904m	14	6	2	3	4	1	5	10408m
7	6	5	3	2	1	4	6088m	15	6	2	3	5	4	1	8448m

5.1. Example: job shop layout design:

Remark: What to do if rooms have unequal sizes?



Practical constraint:

$$\frac{\text{lenght}}{\text{width}} \leq 3$$

Only those solutions are feasible in which for each room the elementary areas are adjacent.

5.2. Example: job shop layout design:

Objective:

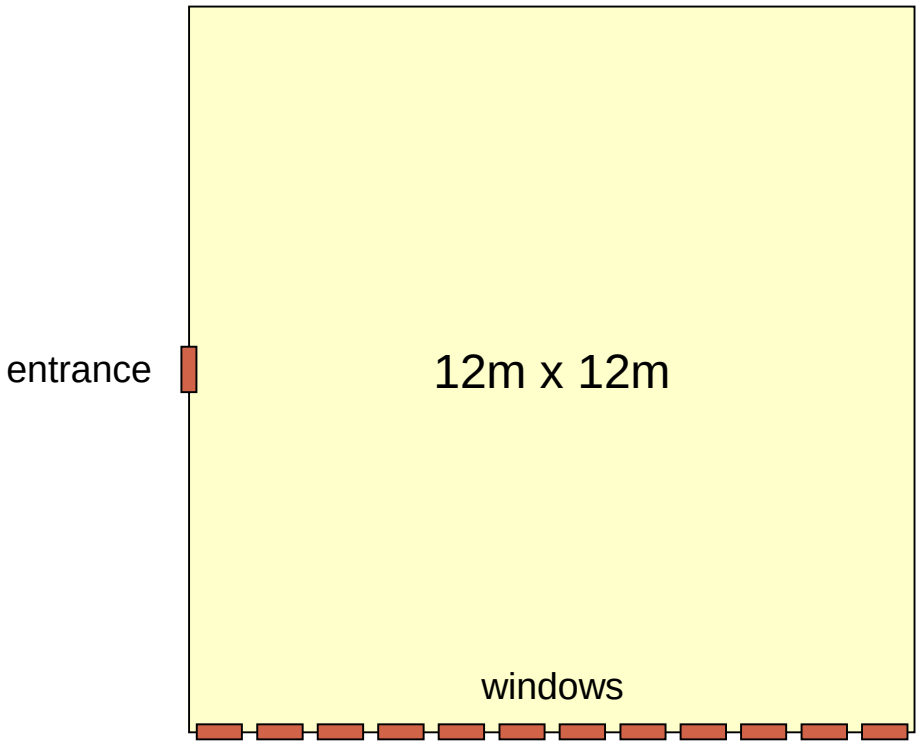
Design an editorial office layout that meets every employee's preferences (**qualitative** criterion!) as much as possible.

Step 1: Agree on the required space needed per function/equipment

function	m² needed	equipment	m² needed
Main editor	15	Archive	20
Secretary	16	Fax	1
Editors	40	Copier	2
Conservator	12		
DT publisher	10		
Production mgr.	15		

5.2. Example: job shop layout design:

Step 2: Check whether or not the available area is big enough

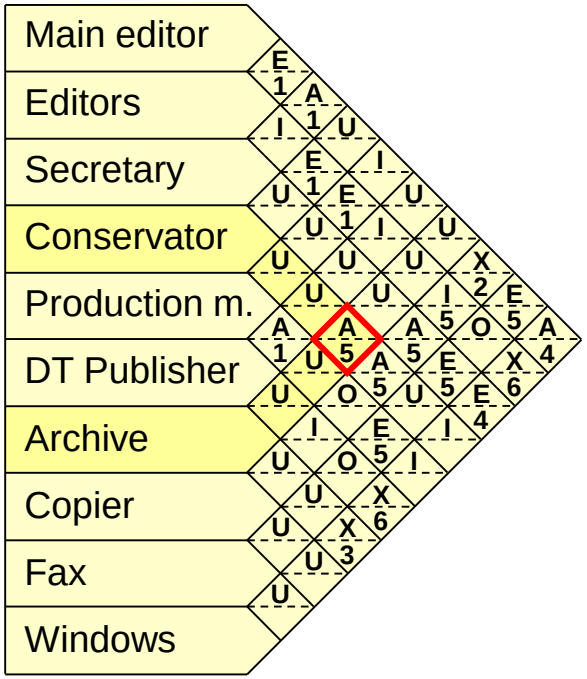


131m² < 144m²

OK!

5.2. Example: job shop layout design:

Step 3: Put all stakeholders' preferences in a relation diagramme

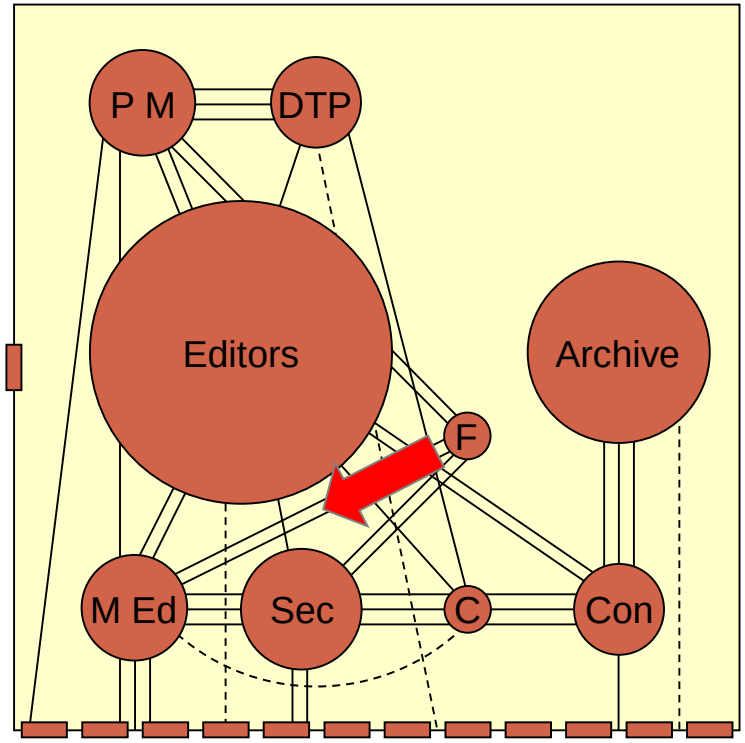


Symbol	Proximity
A	Absolutely necessary
E	Especially important
I	Important
O	Ordinary close
U	Unimportant
X	Undesirable

Code	Reason
1	Personal contact
2	Noise
3	Climatisation
4	Visitors
5	Frequent use
6	Screen reflexions

5.2. Example: job shop layout design:

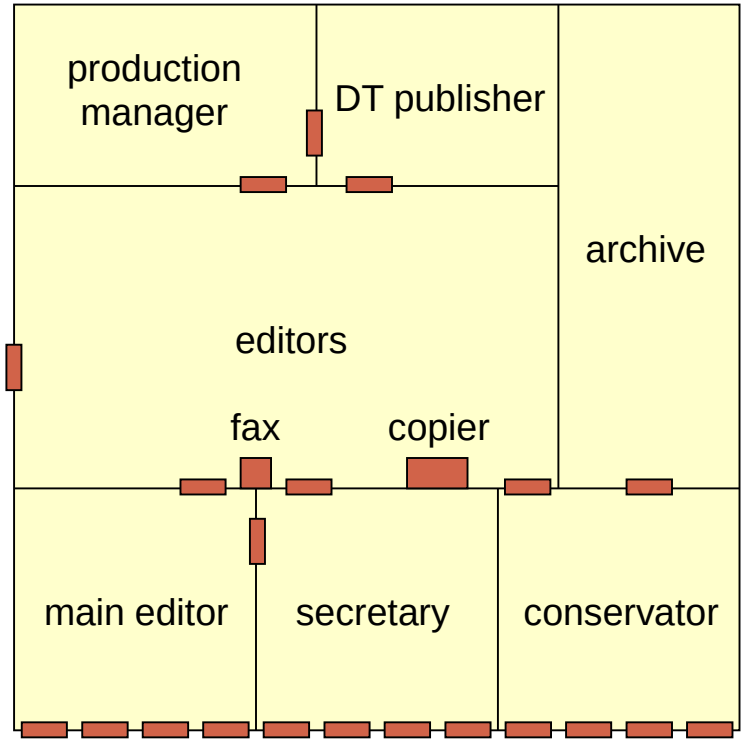
Step 4: Draw a contact intensity graph



Symbol	Intensity
A	
E	
I	
O	
U	
X	

5.2. Example: job shop layout design:

Step 5: Replace circles by proportional adjacent rectangles



5.3. Example: flow shop layout design:

Objective:

Design a balanced production line for continuous production of 40 products P/day. Assume 8 working hours a day.

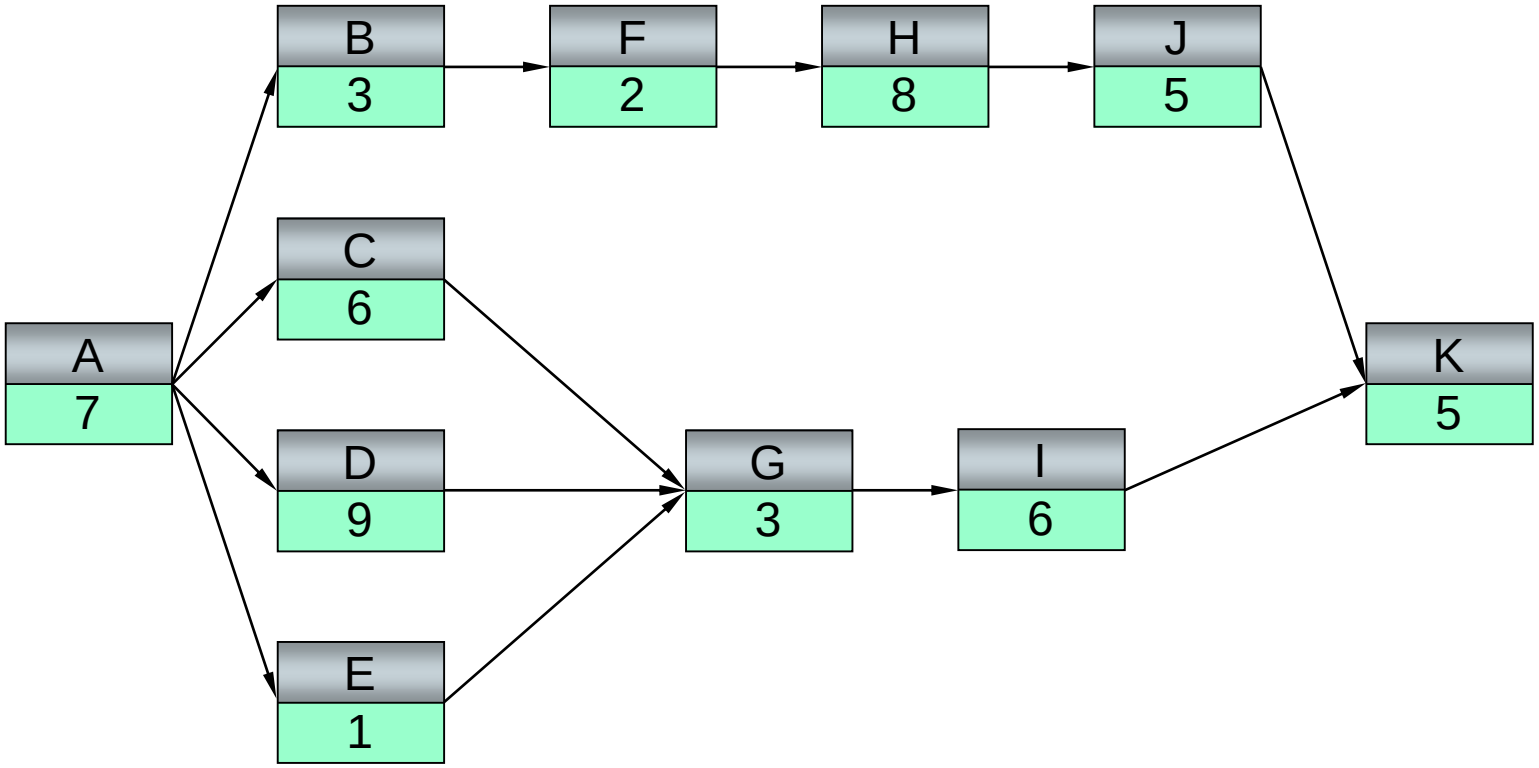
5.3. Example: flow shop layout design:

Step 1: Determine precedence relations

Task	Duration (minutes)	Must immediately follow
A	7	-
B	3	A
C	6	A
D	9	A
E	1	A
F	2	B
G	8	C, D and E
H	3	F
I	5	G
J	6	H
K	5	I and J

5.3. Example flow shop layout design:

Step 2: Draw a precedence diagramme



5.3. Example: flow shop layout design:

Step 3: Calculate cycle time

Cycle time = the time a product spends at a work station

= production time available per day/units required per day

= 8 hours/day / 40 products/day

= 0,2 hours/product

= 12 minutes/product

5.3. Example: flow shop layout design:

Step 4: Calculate minimum required number of work stations

$$\text{Min. \# work stations} = \frac{\sum_{i=1}^{N} \text{duration of task i}}{\text{cycle time}}$$

$$= \frac{7+3+6+9+1+2+3+8+6+5+5}{12}$$

$$= 4{,}58 \text{ thus } 5 \text{ work stations}$$

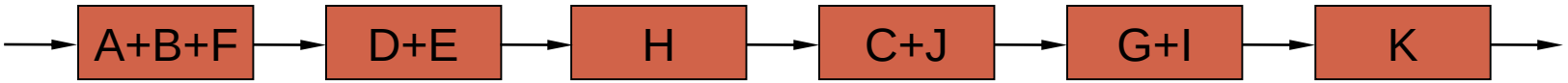
5.3. Example: flow shop layout design:

Step 5: Assign tasks to work centres (using longest task time heuristic)

Work station	Task candidates	Assigned task	Task duration	Station time	Idle time
1	A	A	7	12	0
	B, C, D, E	B	3		
	C, D, E, F	F	2		
2	C, D, E, H	D	9	10	2
	C, E, H	E	1		
3	C, H	H	8	8	4
4	C, J	C	6	11	1
	G, J	J	5		
5	G	G	3	9	3
	I	I	6		
6	K	K	5	5	7

5.3. Example: flow shop layout design:

Step 6: Calculate assembly line efficiency



$$\text{Efficiency} = \frac{\sum_{i=1}^{N} \text{duration of task i}}{\text{actual \# workstations} \times \text{largest assigned cycle time}}$$

$$= \frac{55 \text{ minutes}}{6 \text{ workstations} \times 12 \text{ minutes/workstation}}$$

$$= 76{,}4\%$$

5.4. Example: work cell layout design:

Objective:

Design work cells with a limited number of machines (A, B, C, D, E) to produce following 8 products (1, 2, 3, 4, 5, 6, 7, 8).

Step 1: Draw a process steps matrix

	1	2	3	4	5	6	7	8
A		X			X		X	
B		X	X		X			
C	X			X		X	X	X
D			X	X		X		X
E	X					X		

5.4. Example: work cell layout design:

Step 2: Use a technique to create product families:

Rank Order Clustering (ROC)

	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0	
	1	2	3	4	5	6	7	8	
A		X			X		X		74
B		X	X		X				104
C	X			X		X	X	X	151
D			X	X		X		X	53
E	X					X			132

5.4. Example: work cell layout design:

Step 2: Use a technique to create product families:

Rank Order Clustering (ROC)

		1	2	3	4	5	6	7	8	
2^4	C	X			X		X	X	X	151
2^3	E	X					X			132
2^2	B		X	X		X				104
2^1	A		X			X		X		74
2^0	D			X	X		X		X	53
		24	6	5	17	6	25	18	17	

5.4. Example: work cell layout design:

Step 2: Use a technique to create product families:

Rank Order Clustering (ROC)

	6	1	7	4	8	2	5	3	
C	X	X	X	X	X				248
E	X	X							192
B						X	X	X	7
A			X			X	X		38
D	X			X	X			X	153
	25	24	18	17	17	6	6	5	

5.4. Example: work cell layout design:

Step 2: Use a technique to create product families:

Rank Order Clustering (ROC)

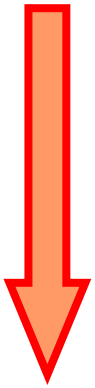
	6	1	7	4	8	2	5	3	
C	X	X	X	X	X				248
E	X	X							192
D	X			X	X			X	153
A			X			X	X		38
B						X	X	X	7
	28	24	18	20	20	3	3	5	

5.4. Example: work cell layout design:

Step 2: Use a technique to create product families:

Rank Order Clustering (ROC)

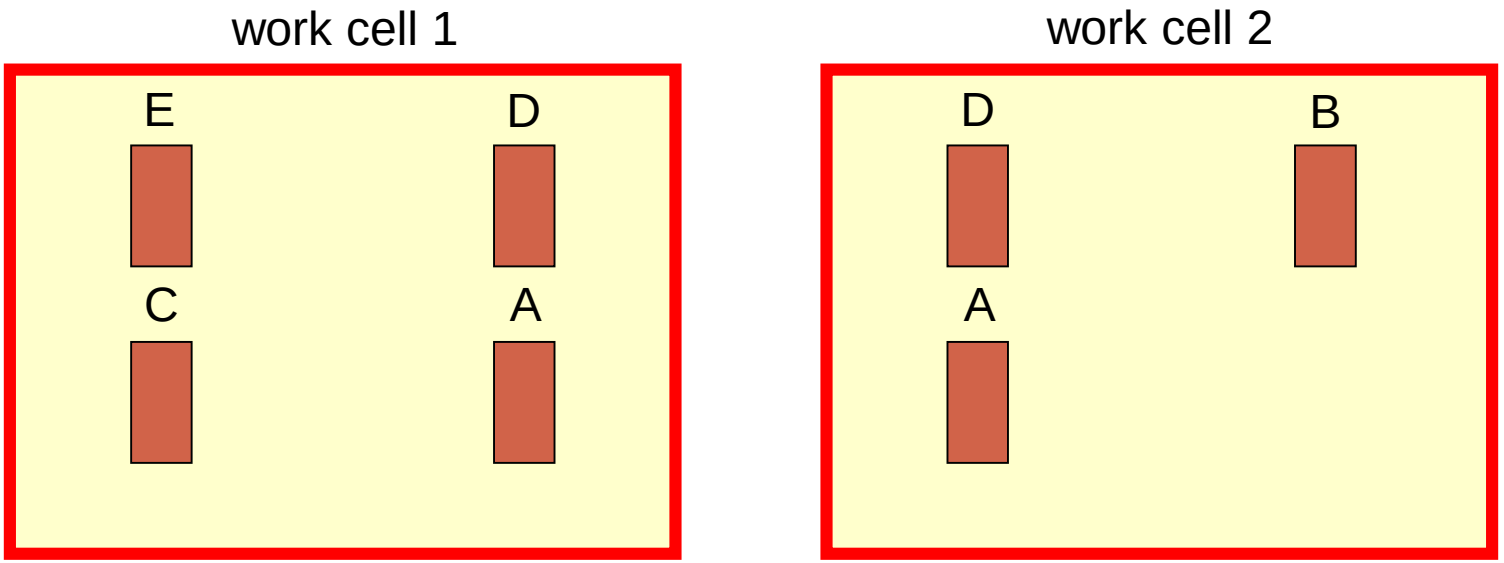
	6	1	8	4	7	3	5	2	
C	X	X	X	X	X				248
E	X	X							192
D	X		X	X		X			180
A					X		X	X	11
B						X	X	X	7
	28	24	20	20	18	5	3	3	



5.4. Example: work cell layout design:

Step 2: Use a technique to create product families:

Rank Order Clustering (ROC)



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