Lean Manufacturing Management Analytics

Manufacturing Facility Planning and Management

भारतीय प्रौद्योगिकी संस्थान दिल्ली
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Outline

- Objectives of Layout
  - Quantitative/ Qualitative
- Basic Layouts
  - Process/ Product/ Fixed/ Hybrid or Cellular layouts
- Designing Process Layouts
  - Block Diagramming/ Relational Chart/ Softwares
  - QAP Model for Process Layout
- Designing Product Layouts
  - Assembly Line Balancing
- Hybrid (Cellular) Layout
- Clustering Approach for Cellular Layouts
  - Rank order clustering
  - Row and column masking

Objectives of Facility Planning

- Minimize material-handling costs
- Utilize space efficiently
- Utilize labor efficiently
- Eliminate bottlenecks
- Facilitate communication and interaction
- Reduce manufacturing cycle time
- Reduce customer service time
- Eliminate wasted or redundant movement

- Facilitate entry, exit, and placement of material, products, and people
- Incorporate safety and security measures
- Promote product and service quality
- Encourage proper maintenance activities
- Provide a visual control of activities
- Provide flexibility to adapt to changing conditions
- Increase capacity

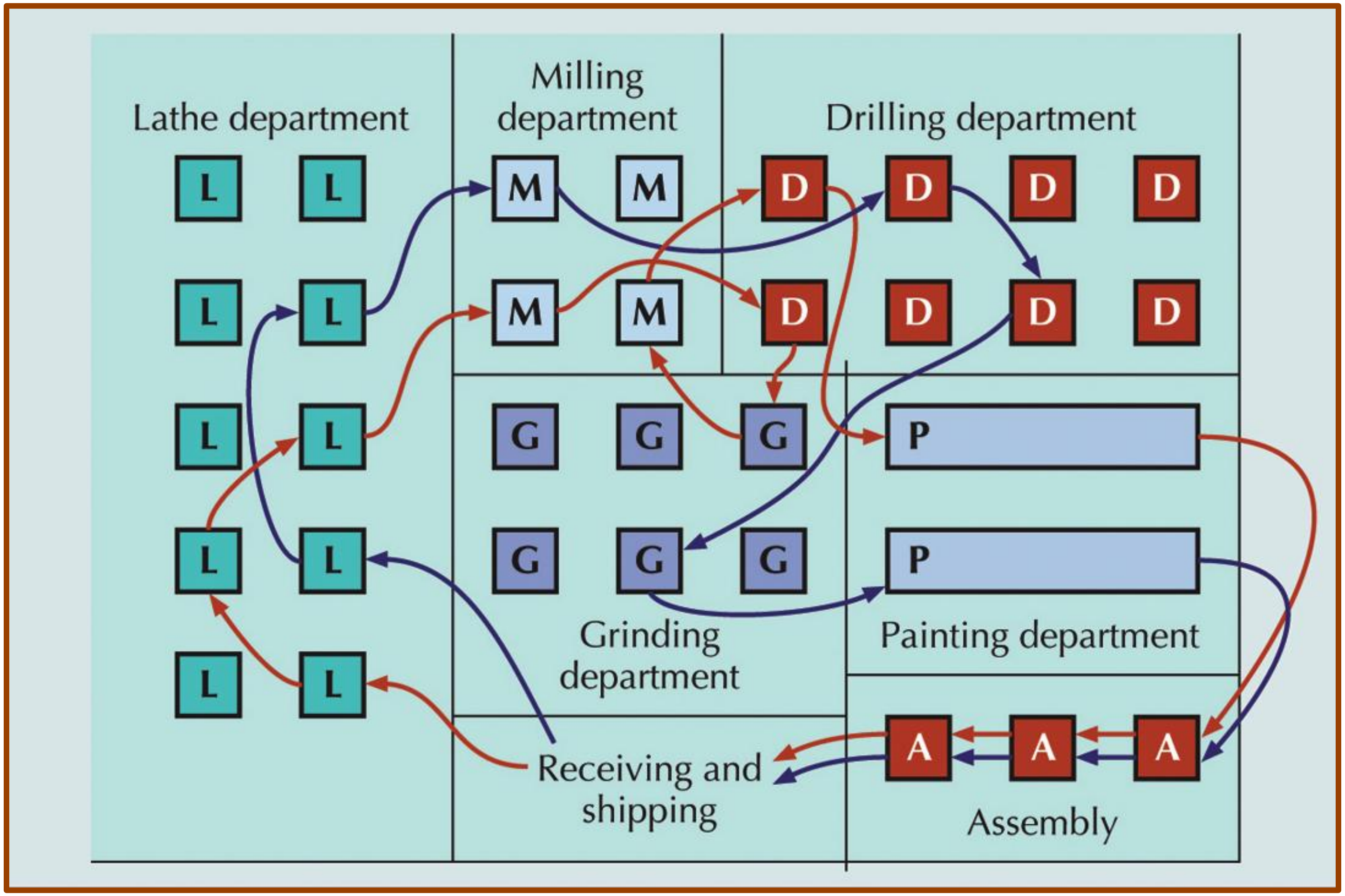
Process-Oriented Layout

- ☑ Like machines and equipment are grouped together
- ☑ Flexible and capable of handling a wide variety of products or services
- ☑ Scheduling can be difficult and setup, material handling, and labor costs can be high

Process Layout in Services Industry

Men's wear	Shoes	Housewares
Women's dresses	Cosmetics and jewelry	Children's department
Sportswear	Entry and display area	Food court

Process Layout in Manufacturing Industry



Methods to Design Process Layouts

- Goal: minimize material handling costs
- Block Diagramming
  - minimize nonadjacent loads
  - use when quantitative data is available

Quantitative Method

- Relationship Diagramming
  - based on location preference between areas
  - use when quantitative data is not available

Qualitative Method

- ☑ Arrange work centers so as to minimize the costs of material handling

- ☑ Basic cost elements are
  - ☑ Number of loads (or people) moving between centers
  - ☑ Distance loads (or people) move between centers

$$\text{Minimize cost} = \sum_{i=1}^{n} \sum_{j=1}^{n} X_{ij} C_{ij}$$

where

n	=	total number of work centers or departments
i, j	=	individual departments
X_{ij}	=	number of loads moved from department i to department j
C_{ij}	=	cost to move a load between department i and department j

Example 1

Arrange six departments in a factory to minimize the material handling costs. Each department is 20 x 20 feet and the building is 60 feet long and 40 feet wide.

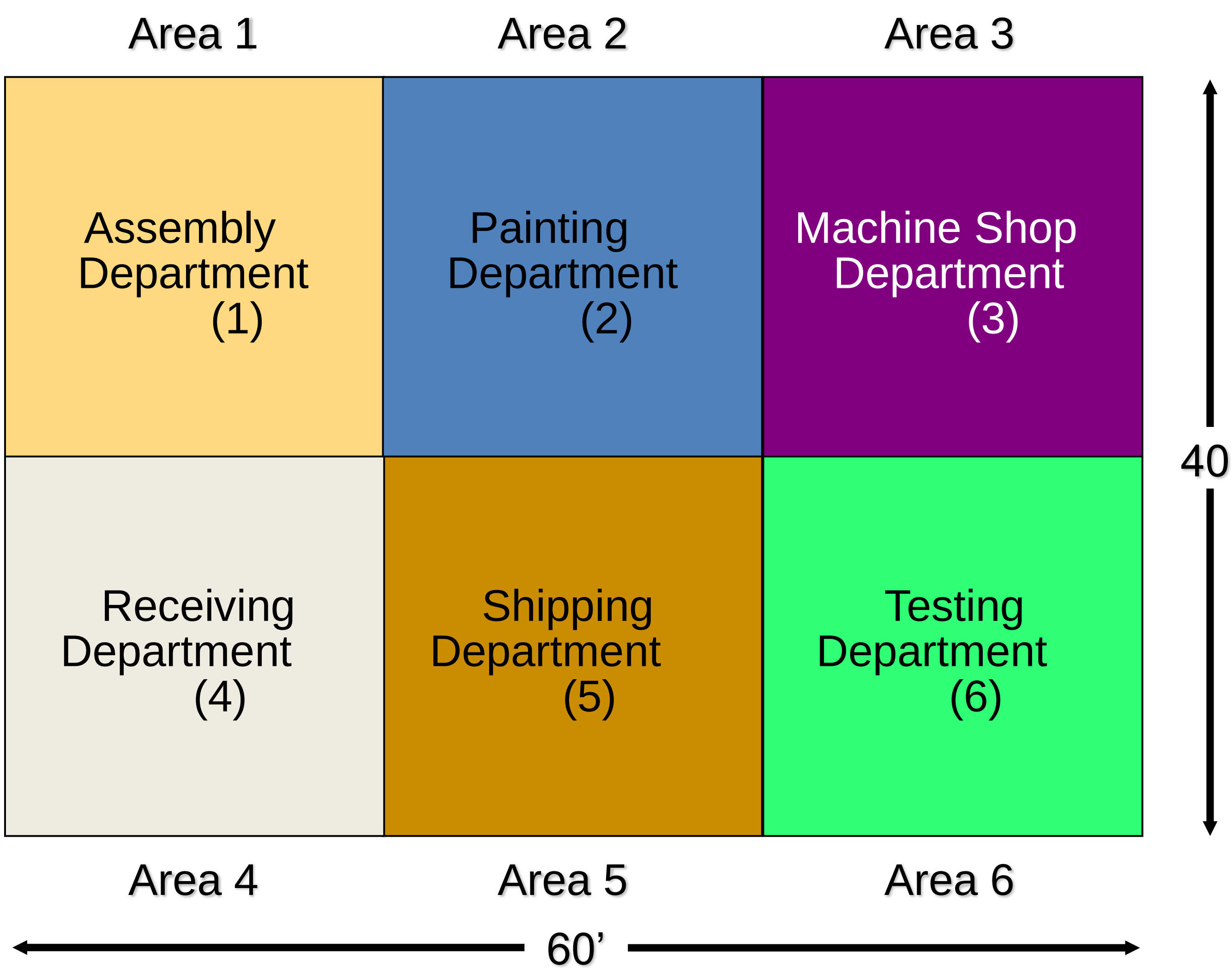
1. Construct a “from-to matrix”
2. Determine the space requirements
3. Develop an initial schematic diagram
4. Determine the cost of this layout
5. Try to improve the layout
6. Prepare a detailed plan

Number of loads per week

Department	Assembly (1)	Painting (2)	Machine Shop (3)	Receiving (4)	Shipping (5)	Testing (6)
Assembly (1)		50	100	0	0	20
Painting (2)			30	50	10	0
Machine Shop (3)				20	0	100
Receiving (4)					50	0
Shipping (5)						0
Testing (6)						

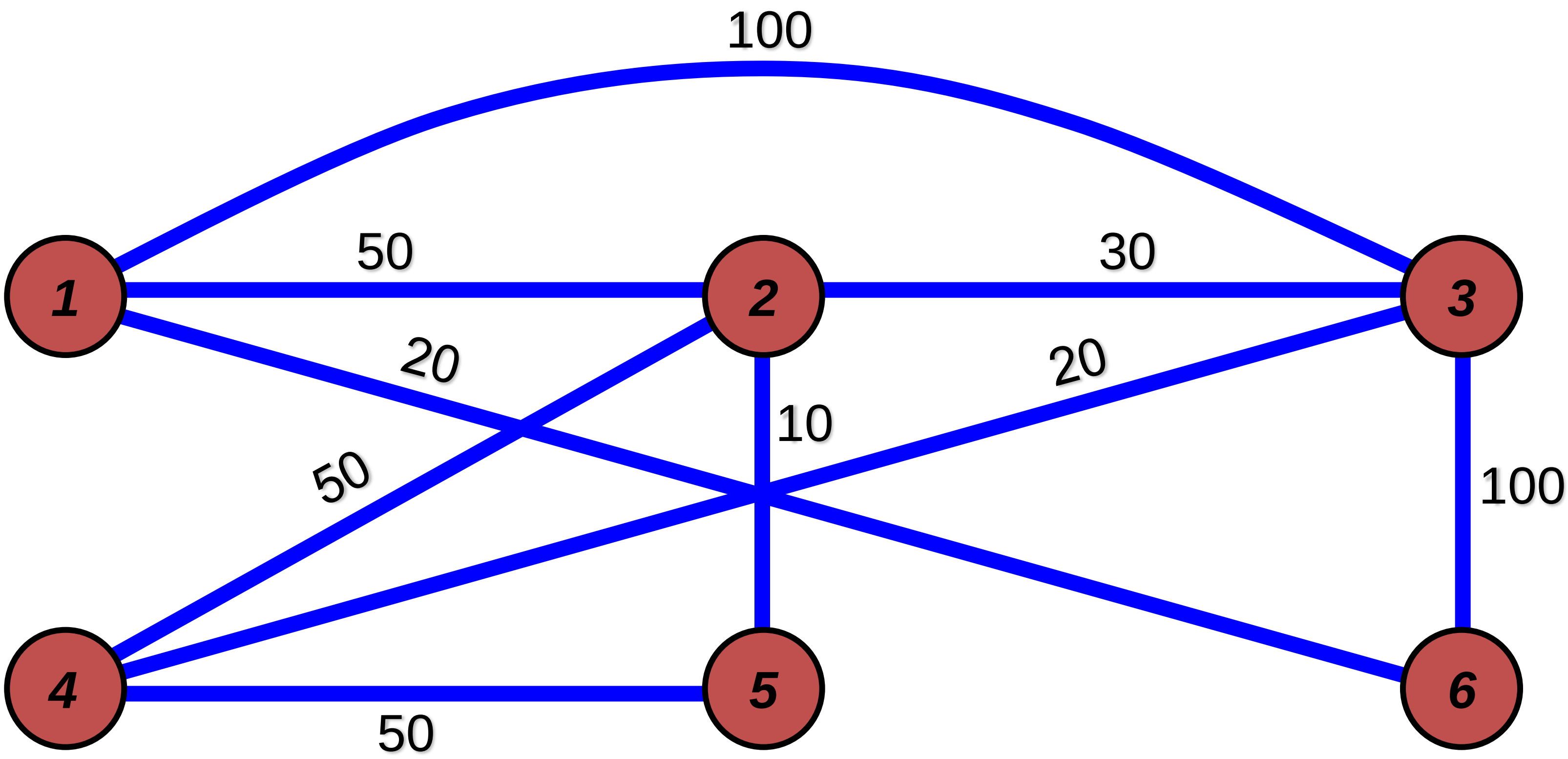
Solution

Initial Random Layout



Figure

Interdepartmental Flow Graph



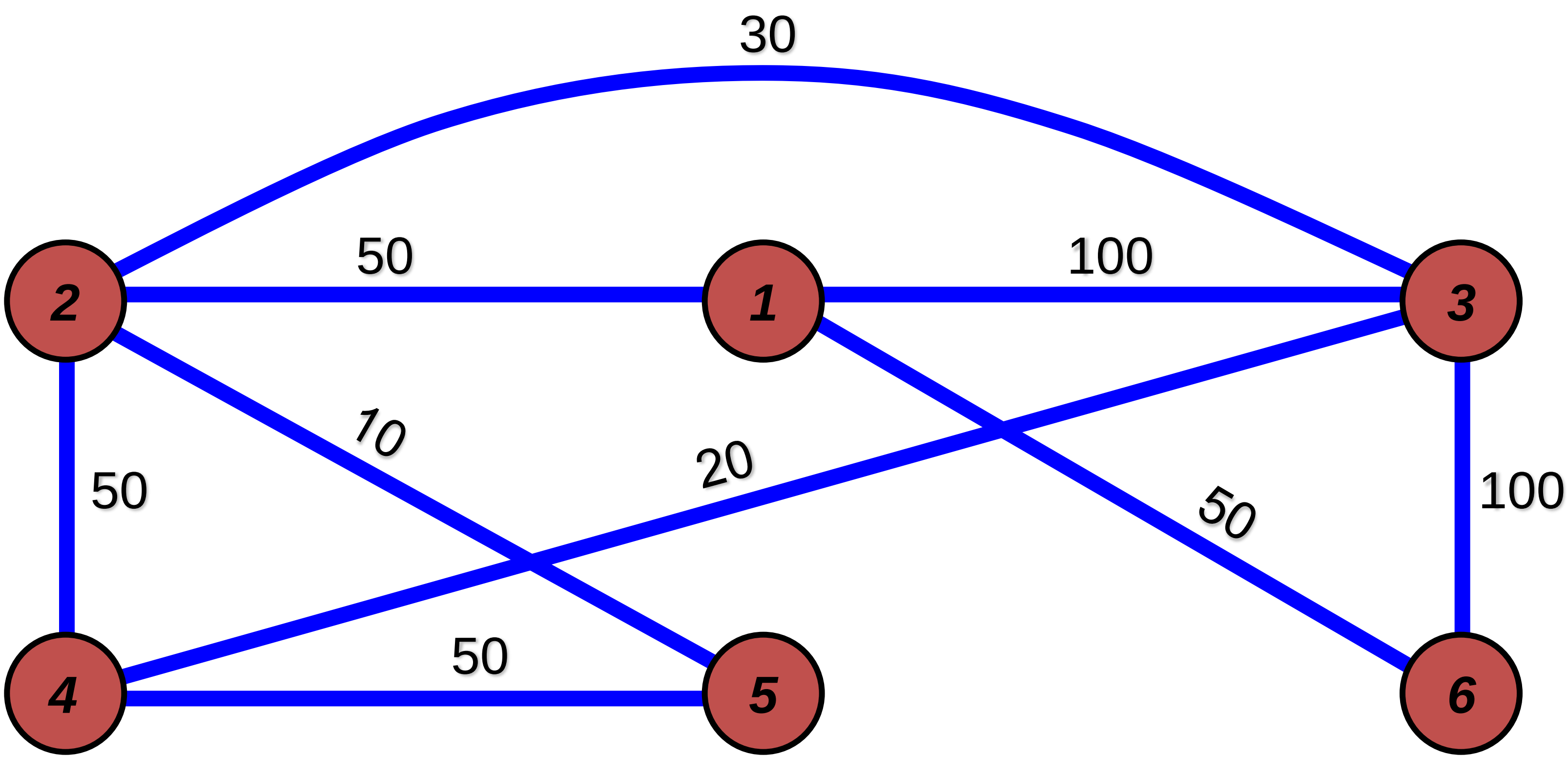
Figure

$$\text{Cost} = \sum_{i=1}^{n} \sum_{j=1}^{n} X_{ij}\, C_{ij}$$

Cost =	\$50 (1 and 2)	+	\$200 (1 and 3)	+	\$40 (1 and 6)
+	\$30 (2 and 3)	+	\$50 (2 and 4)	+	\$10 (2 and 5)
+	\$40 (3 and 4)	+	\$100 (3 and 6)	+	\$50 (4 and 5)

= \$570

Revised Interdepartmental Flow Graph



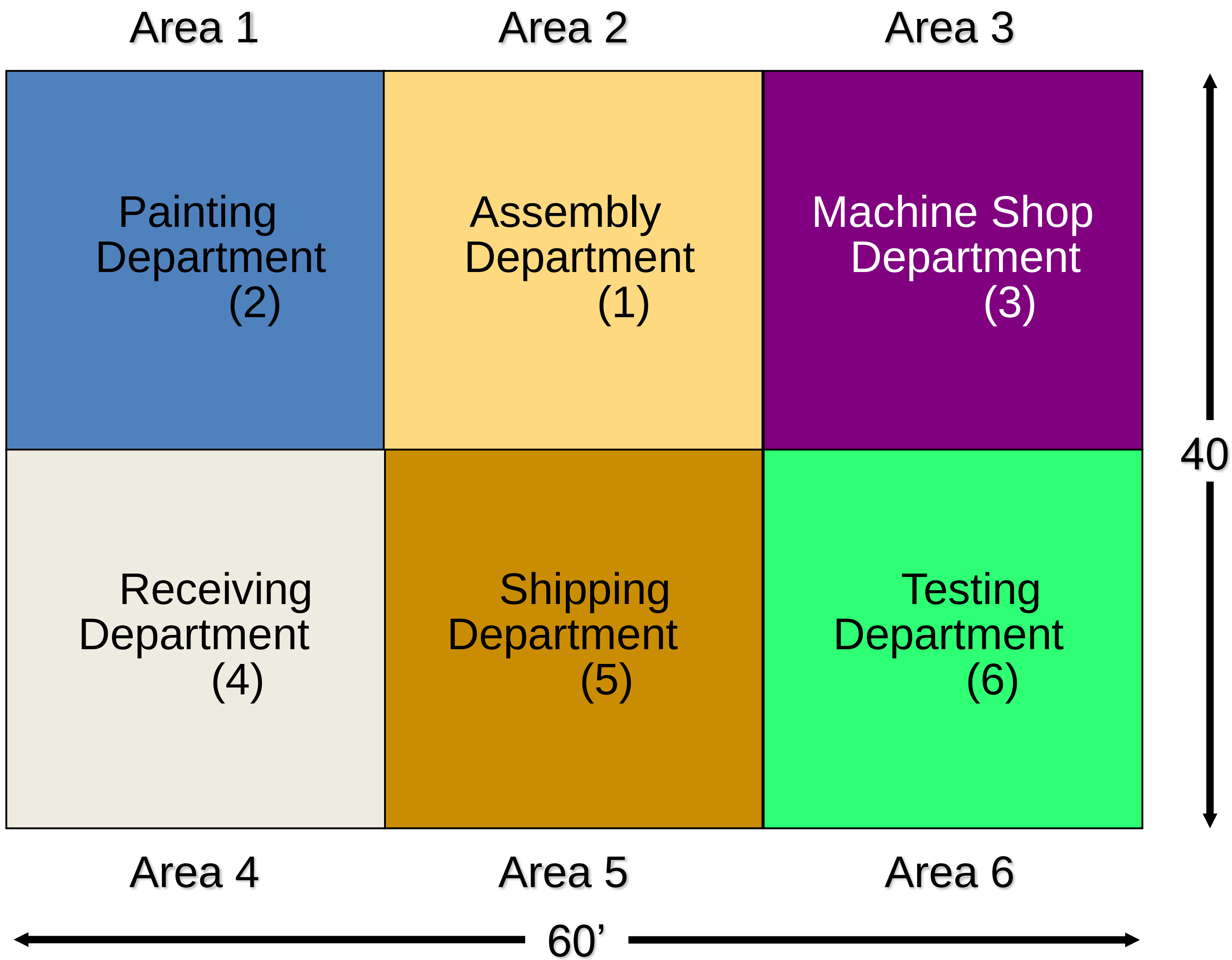
Figure

$$\text{Cost} = \sum_{i=1}^{n} \sum_{j=1}^{n} X_{ij}\, C_{ij}$$

$$\begin{array}{lcccccc}
\text{Cost} & = & \underset{(1 \text{ and } 2)}{\$50} & + & \underset{(1 \text{ and } 3)}{\$100} & + & \underset{(1 \text{ and } 6)}{\$20} \\
 & + & \underset{(2 \text{ and } 3)}{\$60} & + & \underset{(2 \text{ and } 4)}{\$50} & + & \underset{(2 \text{ and } 5)}{\$10} \\
 & + & \underset{(3 \text{ and } 4)}{\$40} & + & \underset{(3 \text{ and } 6)}{\$100} & + & \underset{(4 \text{ and } 5)}{\$50}
\end{array}$$

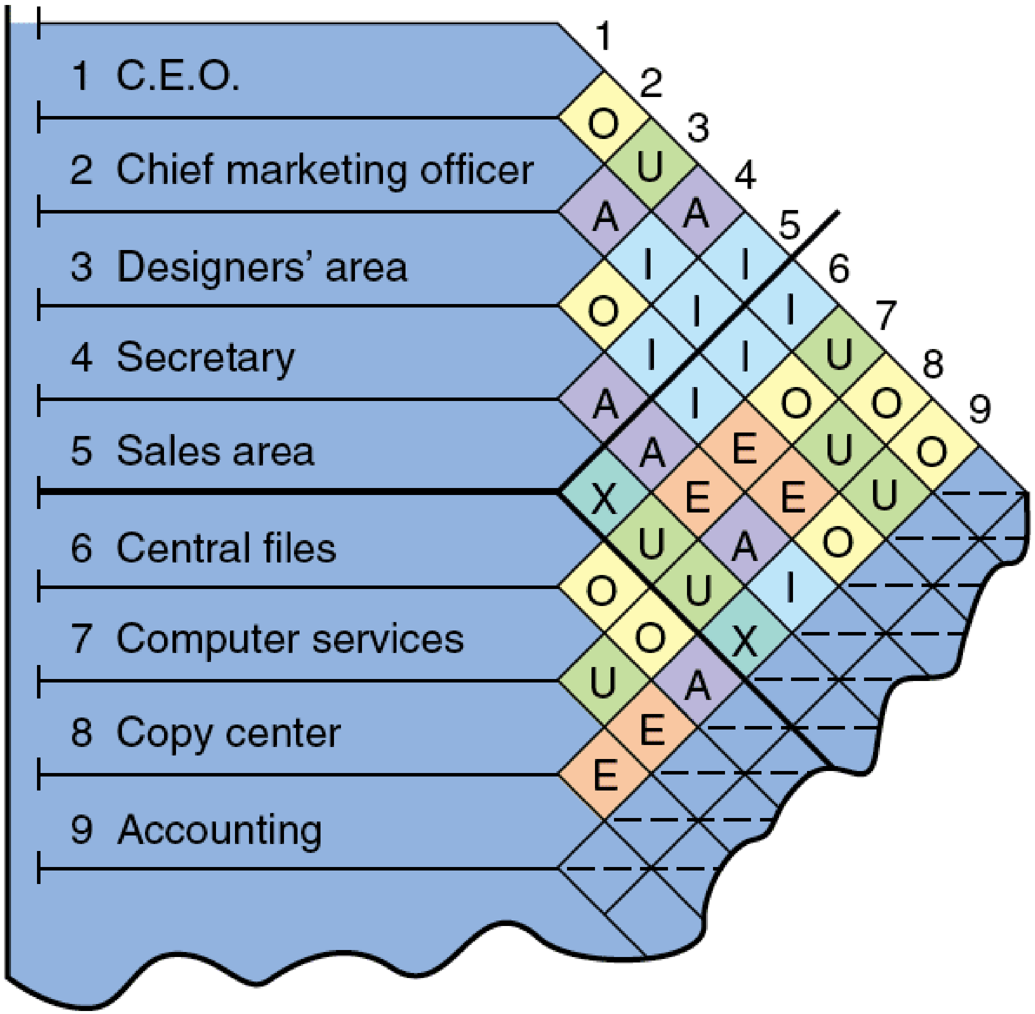
$$= \$480$$

Improved Layout



Figure

Qualitative Layout Design-Relationship Chart

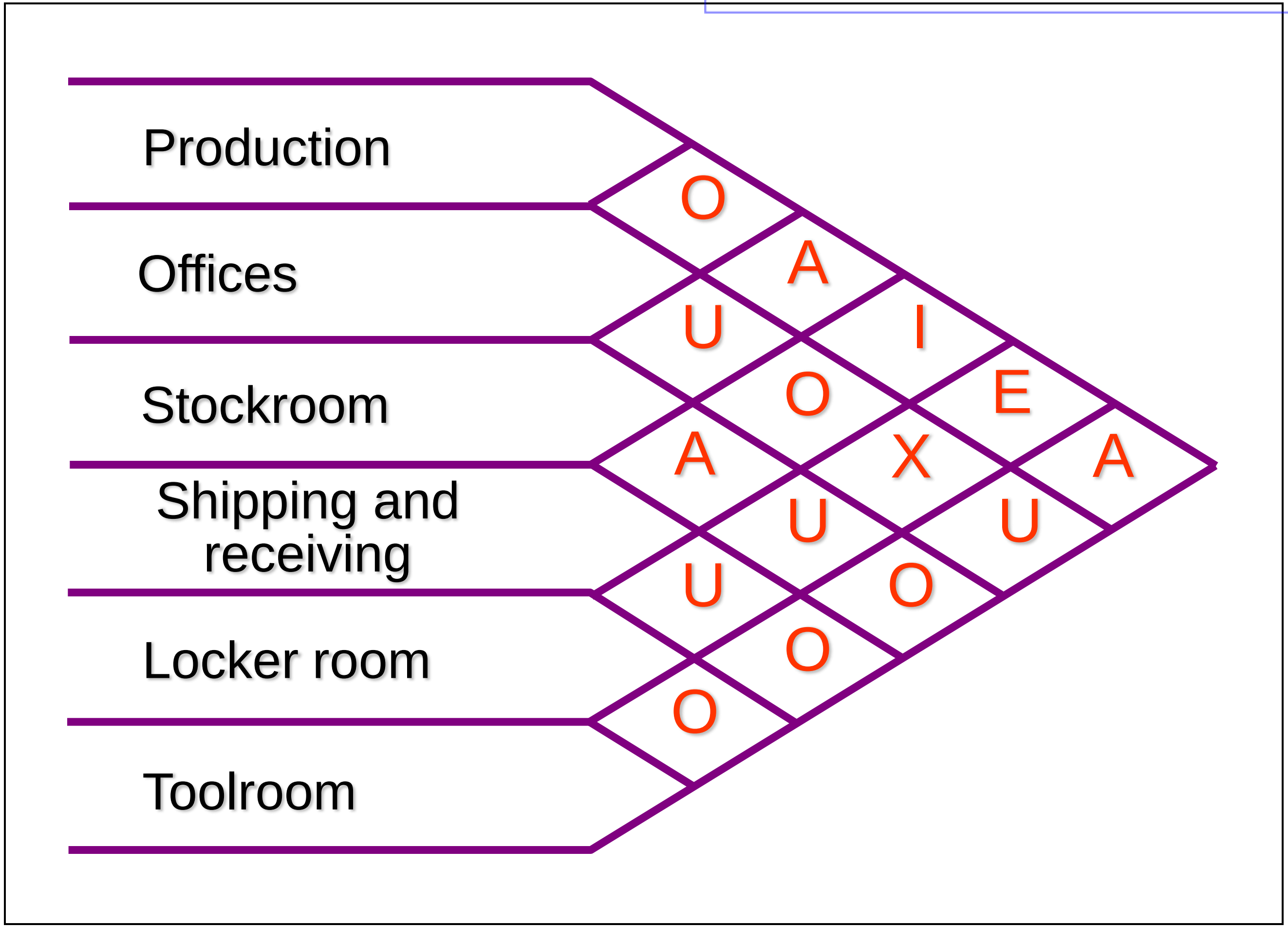


Value	CLOSENESS
A	Absolutely necessary
E	Especially important
I	Important
O	Ordinary OK
U	Unimportant
X	Not desirable

Figure 9.1

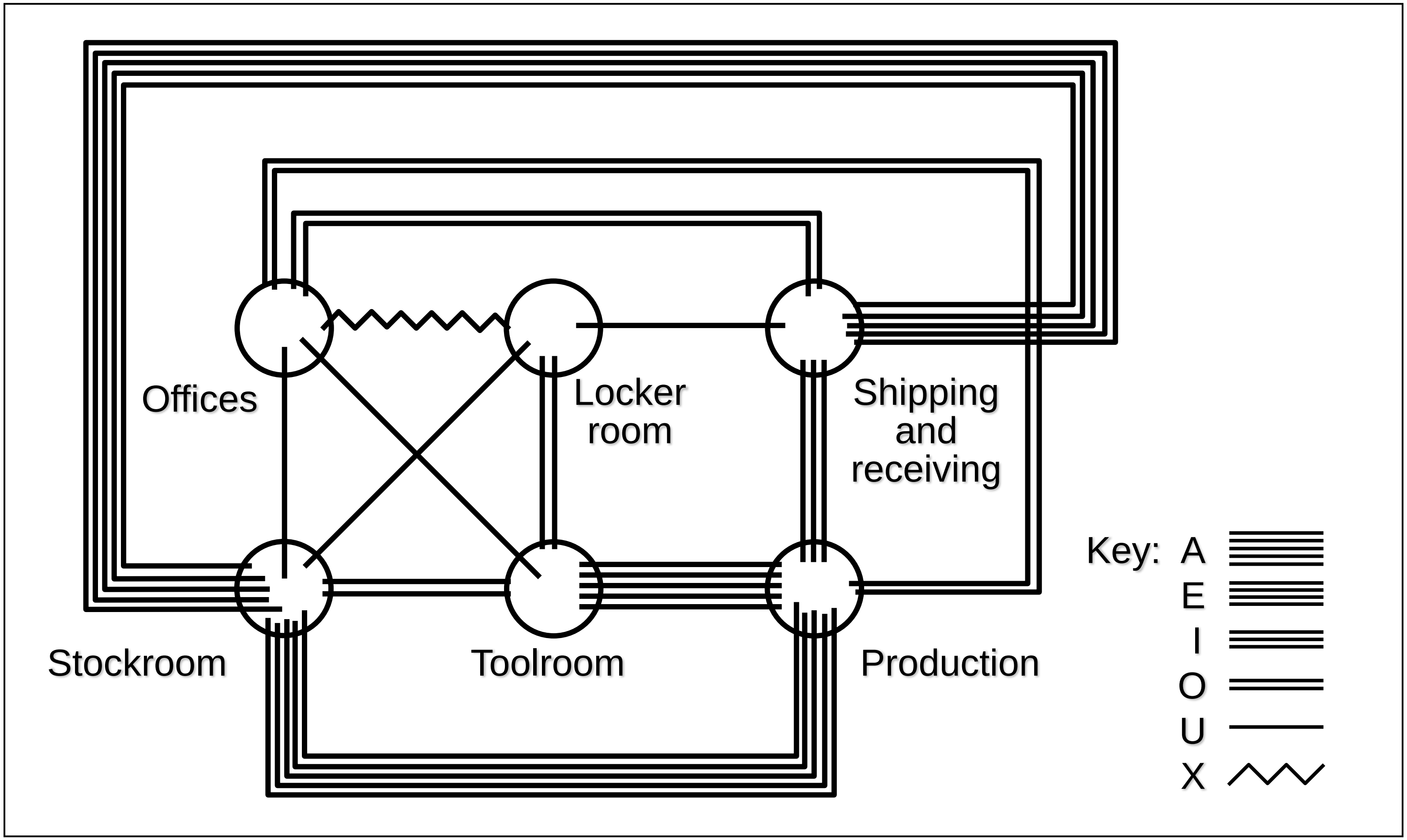
Example 2

A Absolutely necessary
E Especially important
I Important
O Okay
U Unimportant, & X Undesirable

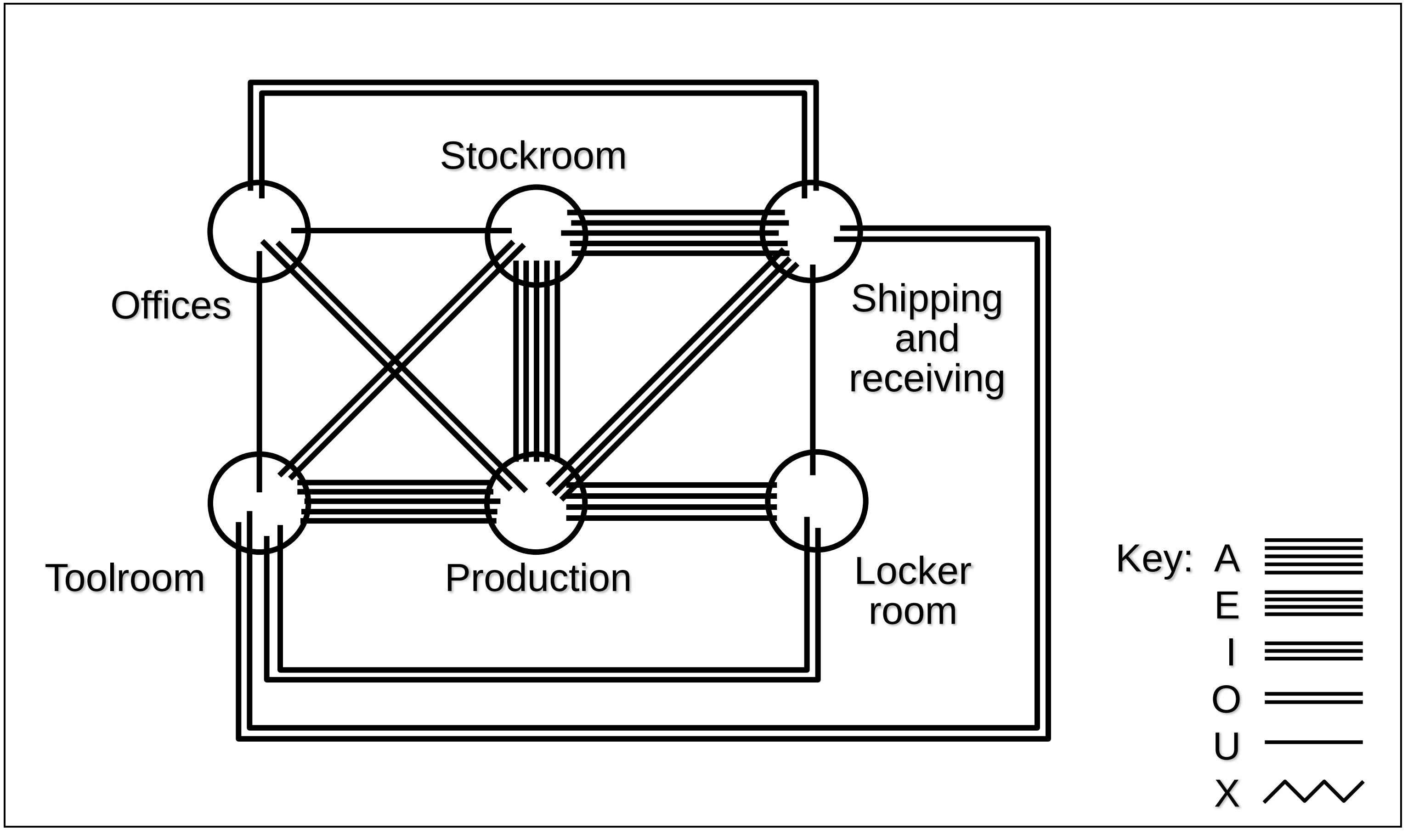


Solution

(a) Relationship diagram of original layout



(b) Relationship diagram of revised layout



Computer Software For Process Layout

- ☑ Graphical approach only works for small problems
- ☑ Computer programs are available to solve bigger problems
  - ☑ CRAFT
  - ☑ ALDEP
  - ☑ CORELAP
  - ☑ Factory Flow

Example 3 (Using CRAFT)

PATTERN

	1	2	3	4	5	6
1	A	A	A	A	B	B
2	A	A	A	A	B	B
3	D	D	D	D	D	D
4	C	C	D	D	D	D
5	F	F	F	F	F	D
6	E	E	E	E	E	D

TOTAL COST 20,100
EST. COST REDUCTION .00
ITERATION 0

(a)

PATTERN

	1	2	3	4	5	6
1	D	D	D	D	B	B
2	D	D	D	D	B	B
3	D	D	D	E	E	E
4	C	C	D	E	E	F
5	A	A	A	A	A	F
6	A	A	A	F	F	F

TOTAL COST 14,390
EST. COST REDUCTION 70.
ITERATION 3

(b)

MATHEMATICAL FORMULATION (QAP)

QAP: (Koopmans & Beckman, 1957)

$$\text{Min } F(X) = \sum_{\substack{i=1 \\ i \neq k}}^{n} \sum_{\substack{j=1 \\ j \neq l}}^{n} \sum_{k=1}^{n} \sum_{l=1}^{n} F_{ik} * D_{jl} * X_{ij} * X_{kl} \qquad (1)$$

$$\sum_{j=1}^{n} X_{ij} = 1 \qquad \text{for all } i=1\ldots n \qquad (2)$$

$$\sum_{i=1}^{n} X_{ij} = 1 \qquad \text{for all } j=1\ldots n \qquad (3)$$

$$X_{ij} = \{0,1\} \qquad \forall \text{ i and j} \qquad (4)$$

X_{ij}= 1 if Facility “i” is located/assigned to location “j”.

X_{ij}= 0 if Facility “i” is not located/assigned to location “j”.

F_{ik} is the flow between two facility i and k.

D_{jl} is the distance between two locations j and l.

n is the number of facilities (departments)

Complexity of SOFLP (QAP)

- For n sized QAP, n facilities are to be assigned at n locations. Therefore the numbers of possible permutations are n! or possible feasible solutions are n! (n factorial).

- To get optimal solution by exact algorithms all n! permutations are to be enumerated that requires huge computational effort. Therefore, exact algorithms for solving QAP are limited to instances of size 20 to 30.

Process Layout (QAP)Example

Arrange six departments in a factory to minimize the material handling costs. Each department is 20 x 20 feet and the building is 60 feet long and 40 feet wide.

Flow Matrix

Number of loads per week

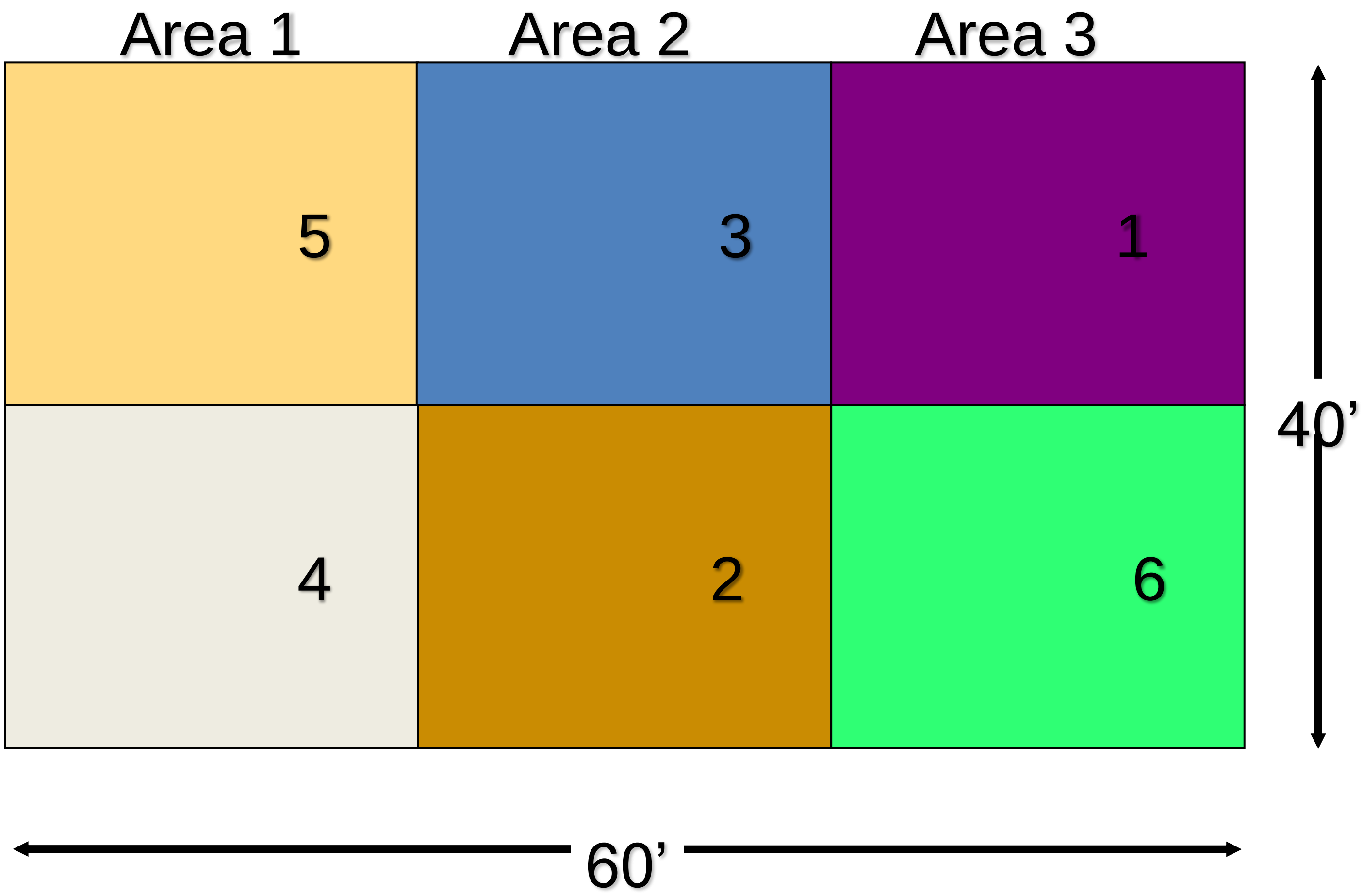
Department	Assembly (1)	Painting (2)	Machine Shop (3)	Receiving (4)	Shipping (5)	Testing (6)
Assembly (1)		50	100	0	0	20
Painting (2)			30	50	10	0
Machine Shop (3)				20	0	100
Receiving (4)					50	0
Shipping (5)						0
Testing (6)						

Distance Matrix

Department	Assembly (1)	Painting (2)	Machine Shop (3)	Receiving (4)	Shipping (5)	Testing (6)
Assembly (1)		1	2	1	1	2
Painting (2)			1	1	1	1
Machine Shop (3)				2	1	1
Receiving (4)					1	2
Shipping (5)						1
Testing (6)						

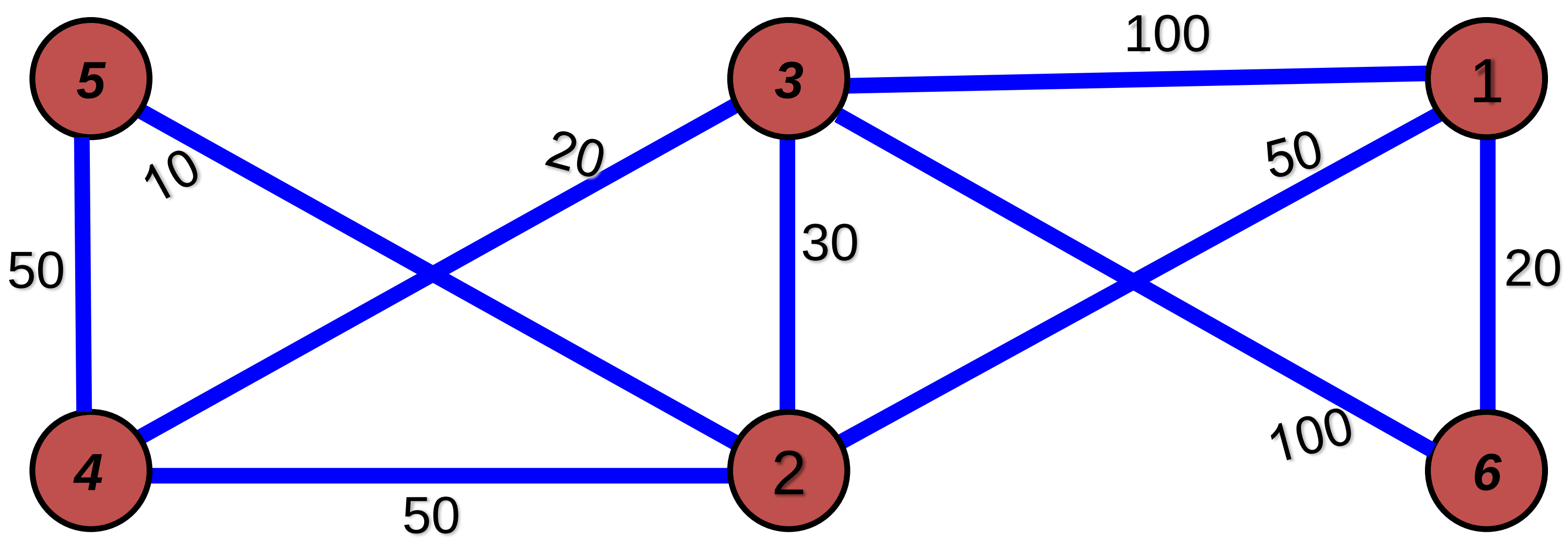
Optimal Solution

- Objective=430



QAP Example

Interdepartmental Flow Graph



Optimal Cost Recheck

$$\text{Cost} = \sum_{i=1}^{n} \sum_{j=1}^{n} X_{ij}\, C_{ij}$$

Cost =		\$50 (1 and 2)	+	\$100 (1 and 3)	+	\$20 (1 and 6)
	+	\$30 (2 and 3)	+	\$50 (2 and 4)	+	\$10 (2 and 5)
	+	\$20 (3 and 4)	+	\$100 (3 and 6)	+	\$50 (4 and 5)

= \$430

Product-Oriented Layout

Organized around products or families of similar high-volume, low-variety products

- ☑ Fabrication line
  - ☑ Builds components on a series of machines
  - ☑ Machine-paced
  - ☑ Require mechanical or engg. changes to balance

- ☑ Assembly line
  - ☑ Puts fabricated parts together at a series of workstations
  - ☑ Paced by work tasks
  - ☑ Balanced by moving tasks

Both types of lines must be balanced so that the time to perform the work at each station is the same

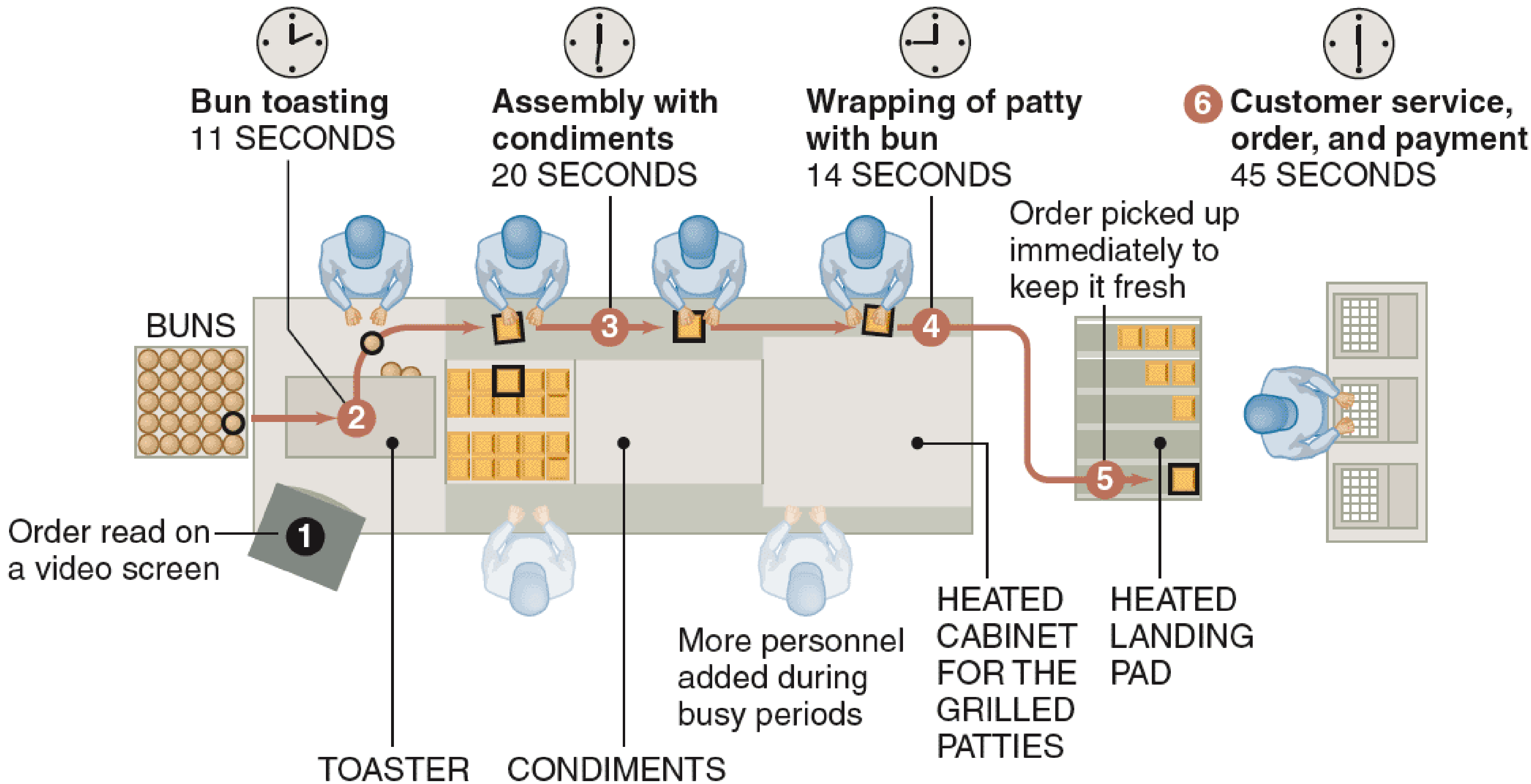
Advantages

1. Low variable cost per unit
2. Low material handling costs
3. Reduced work-in-process inventories
4. Easier training and supervision
5. Rapid throughput

Disadvantages

1. High volume is required
2. Work stoppage at any point ties up the whole operation
3. Lack of flexibility in product or production rates

McDonald's Hamburger Assembly Line



Figure

Example 4

Suppose you load work into the three work stations below such that each will take the corresponding number of minutes as shown. What is the cycle time of this line?

	Station 1 →	**Station 2** →	**Station 3** →
Minutes per Unit	***6***	***7***	***3***

Solution

The cycle time of the line is always determined by the work station taking the longest time. In this problem, the cycle time of the line is 7 minutes. There is also going to be idle time at the other two work stations.

Example 5

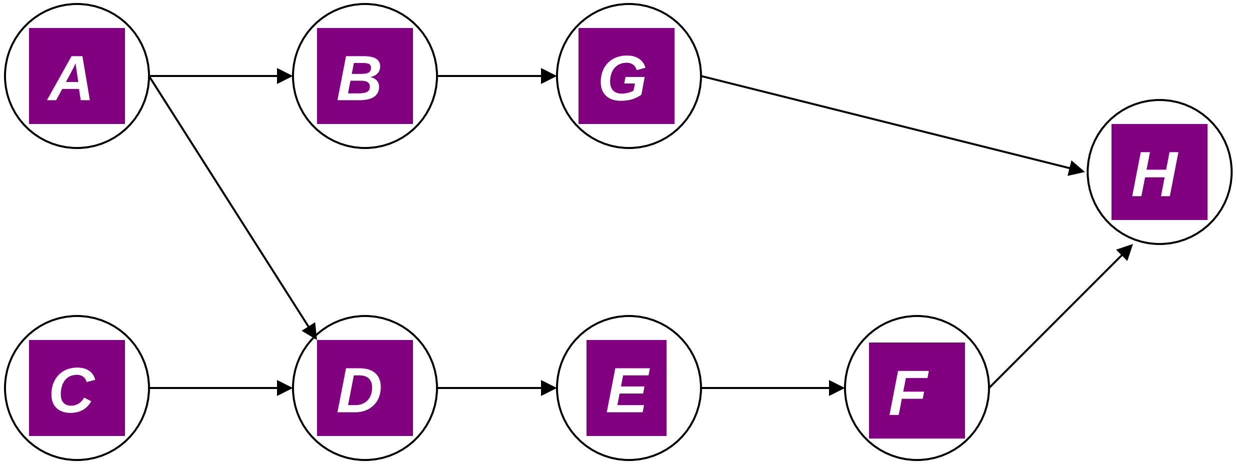
You've just been assigned the job a setting up an electric fan assembly line with the following tasks:

Task	Time (Mins)	Description	Predecessors
A	2	Assemble frame	None
B	1	Mount switch	A
C	3.25	Assemble motor housing	None
D	1.2	Mount motor housing in frame	A, C
E	0.5	Attach blade	D
F	1	Assemble and attach safety grill	E
G	1	Attach cord	B
H	1.4	Test	F, G

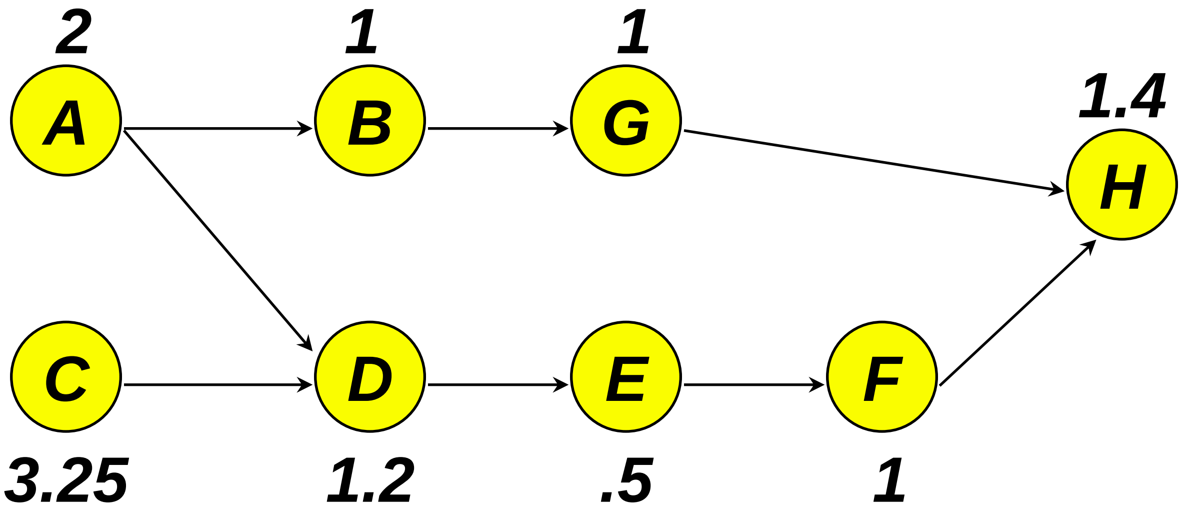
Solution

Task	Predecessors
A	None
B	A
C	None
D	A, C

Task	Predecessors
E	D
F	E
G	B
H	F, G



Question 1: Which process step defines the maximum rate of production?



Answer: Task C is the cycle time of the line and therefore, the maximum rate of production.

Question 2: Suppose we want to assemble 100 fans per day. What would our cycle time have to be?

Answer:

$$\textit{Required Cycle Time}, \mathrm{C} = \frac{\text{Production time per day}}{\text{Required output per period}}$$

$$\mathrm{C} = \frac{420 \text{ mins / day}}{100 \text{ units / day}} = 4.2 \text{ mins / unit}$$

Question 3: What is the theoretical minimum number of workstations for this problem?

Answer:

Theoretical Min. Number of Workstations, N_t

$$N_t = \frac{\text{Sum of task times (T)}}{\text{Cycle time (C)}}$$

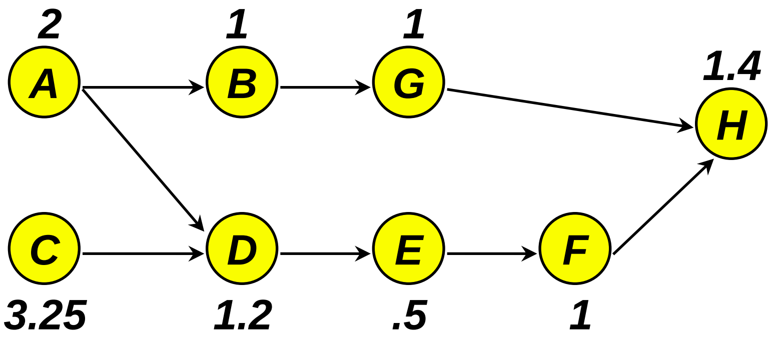
$$N_t = \frac{11.35 \text{ mins / unit}}{4.2 \text{ mins / unit}} = 2.702, \text{ or } 3$$

Rules To Follow for Loading Workstations

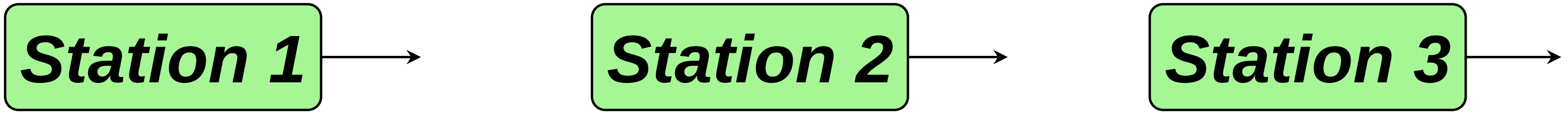
- Assign tasks to station 1, then 2, etc. in sequence. Keep assigning to a workstation ensuring that precedence is maintained and total work is less than or equal to the cycle time. Use the following rules to select tasks for assignment.

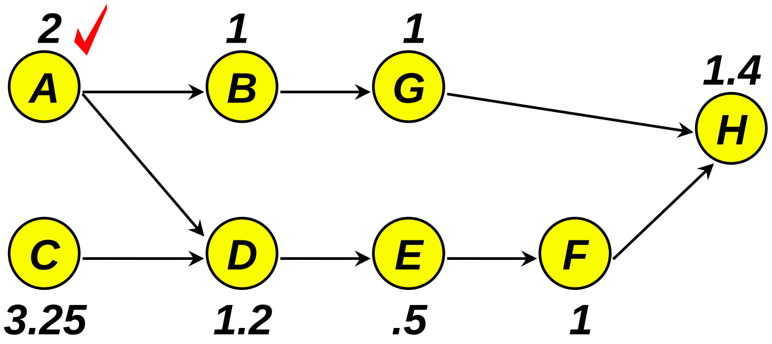
- Primary: Assign tasks in order of the largest number of following tasks

- Secondary (tie-breaking): Assign tasks in order of the longest operating time



Task	Followers	Time (Mins)
A	6	2
C	4	3.25
D	3	1.2
B	2	1
E	2	0.5
F	1	1
G	1	1
H	0	1.4

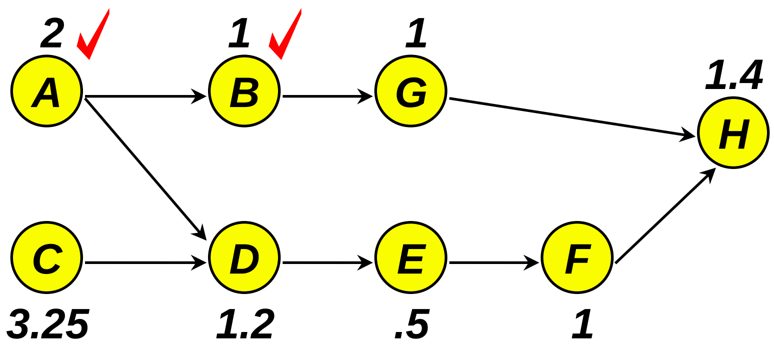




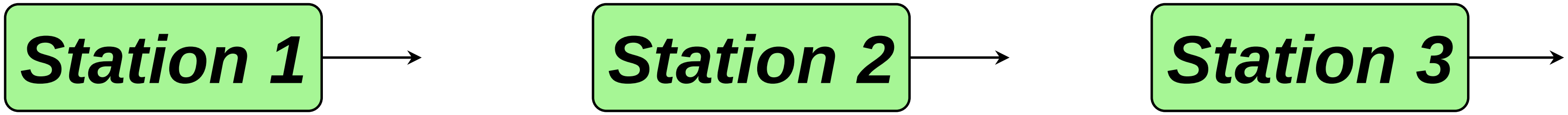
Task	Followers	Time (Mins)
A ✓	6	2
C	4	3.25
D	3	1.2
B	2	1
E	2	0.5
F	1	1
G	1	1
H	0	1.4

Station 1 → **Station 2** → **Station 3** →

***A* (4.2-2=2.2)**

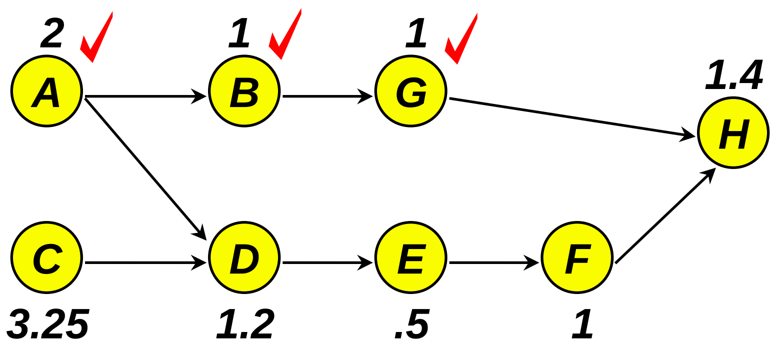


Task	Followers	Time (Mins)
A	6	2
C	4	3.25
D	3	1.2
B	2	1
E	2	0.5
F	1	1
G	1	1
H	0	1.4



A (4.2-2=2.2)

B (2.2-1=1.2)

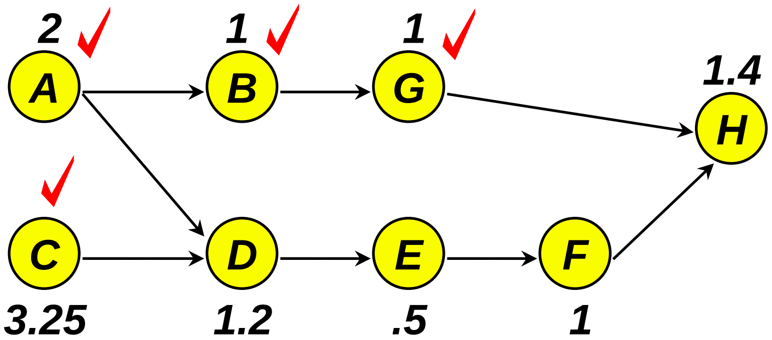


Task	Followers	Time (Mins)
A ✓	6	2
C	4	3.25
D	3	1.2
B ✓	2	1
E	2	0.5
F	1	1
G ✓	1	1
H	0	1.4

Station 1 → **Station 2** → **Station 3** →

A (4.2-2=2.2)
B (2.2-1=1.2)
G (1.2-1= .2)

Idle= .2

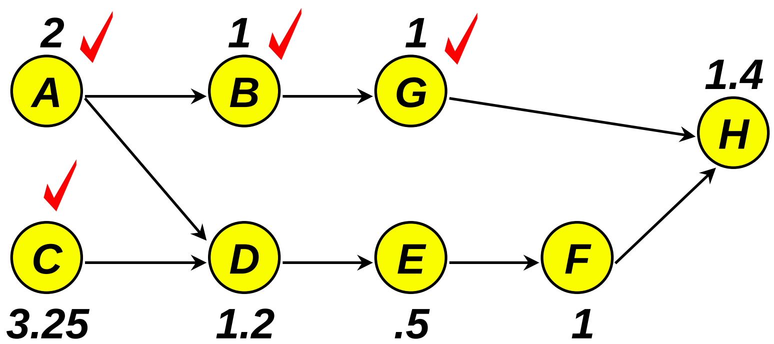


Task	Followers	Time (Mins)
A ✓	6	2
C ✓	4	3.25
D	3	1.2
B ✓	2	1
E	2	0.5
F	1	1
G ✓	1	1
H	0	1.4

Station 1 → **Station 2** → **Station 3** →

Station 1	Station 2	Station 3
A (4.2-2=2.2)	C (4.2-3.25)=.95	
B (2.2-1=1.2)		
G (1.2-1= .2)		

Idle= .2



Task	Followers	Time (Mins)
A ✓	6	2
C ✓	4	3.25
D	3	1.2
B ✓	2	1
E	2	0.5
F	1	1
G ✓	1	1
H	0	1.4

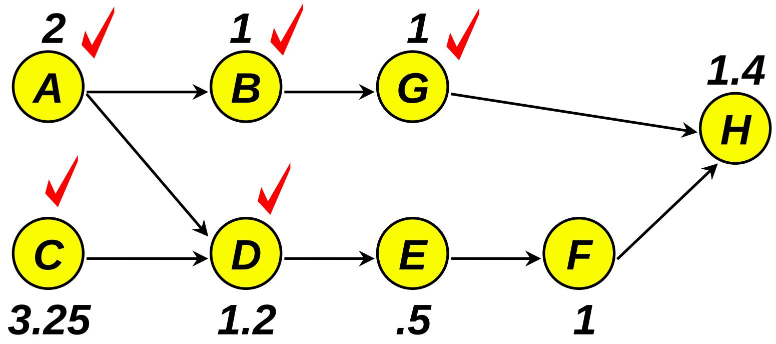
Station 1 → **Station 2** → **Station 3** →

A (4.2-2=2.2)
B (2.2-1=1.2)
G (1.2-1= .2)

C (4.2-3.25)=.95

Idle= .2

Idle = .95



Task	Followers	Time (Mins)
A ✓	6	2
C ✓	4	3.25
D ✓	3	1.2
B ✓	2	1
E	2	0.5
F	1	1
G ✓	1	1
H	0	1.4

Station 1

A (4.2-2=2.2)
B (2.2-1=1.2)
G (1.2-1= .2)

Idle= .2

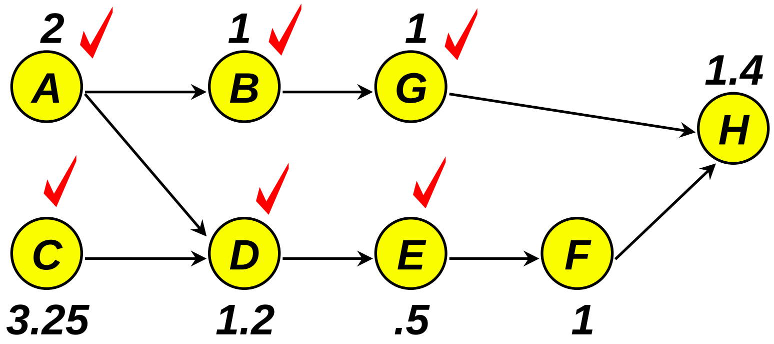
Station 2

C (4.2-3.25)=.95

Idle = .95

Station 3

D (4.2-1.2)=3



Task	Followers	Time (Mins)
A ✓	6	2
C ✓	4	3.25
D ✓	3	1.2
B ✓	2	1
E ✓	2	0.5
F	1	1
G ✓	1	1
H	0	1.4

Station 1 → **Station 2** → **Station 3** →

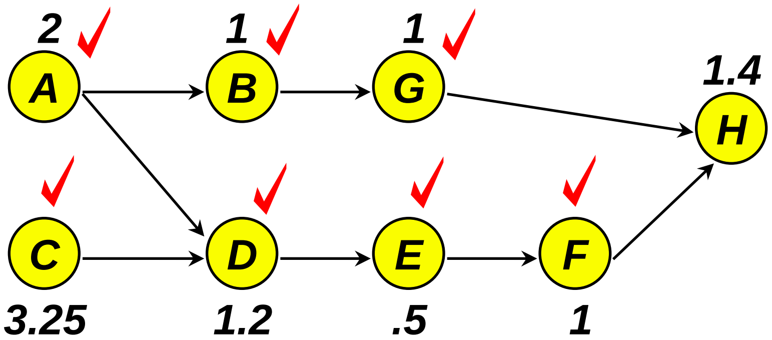
Station 1:
A (4.2-2=2.2)
B (2.2-1=1.2)
G (1.2-1= .2)

Idle= .2

Station 2:
C (4.2-3.25)=.95

Idle = .95

Station 3:
D (4.2-1.2)=3
E (3-.5)=2.5



Task	Followers	Time (Mins)
A ✓	6	2
C ✓	4	3.25
D ✓	3	1.2
B ✓	2	1
E ✓	2	0.5
F ✓	1	1
G ✓	1	1
H	0	1.4

Station 1 → **Station 2** → **Station 3** →

Station 1

A (4.2-2=2.2)

B (2.2-1=1.2)

G (1.2-1= .2)

Idle= .2

Station 2

C (4.2-3.25)=.95

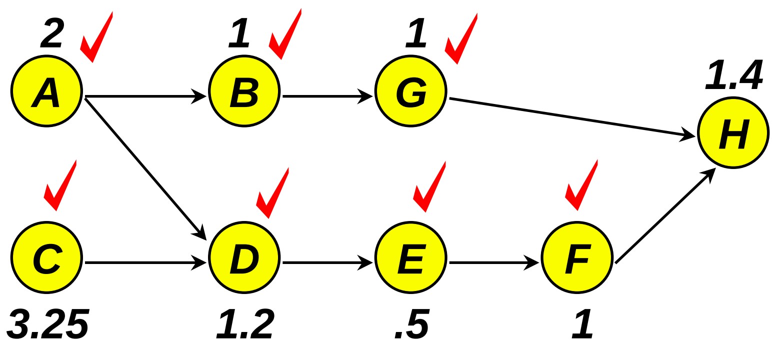
Idle = .95

Station 3

D (4.2-1.2)=3

E (3-.5)=2.5

F (2.5-1)=1.5



Task	Followers	Time (Mins)
A	6	2
C	4	3.25
D	3	1.2
B	2	1
E	2	0.5
F	1	1
G	1	1
H	0	1.4

Station 1	Station 2	Station 3
A (4.2-2=2.2)	C (4.2-3.25)=.95	D (4.2-1.2)=3
B (2.2-1=1.2)		E (3-.5)=2.5
G (1.2-1= .2)		F (2.5-1)=1.5
		H (1.5-1.4)=.1
Idle= .2	Idle = .95	Idle = .1

Question 4: Which station is the bottleneck? What is the effective cycle time?

Answer: Work station is 3 and effective cycle time is 4.1

Question 5: What is the efficiency of assembly line?

Answer:

$$\text{Efficiency} = \frac{\text{Sum of task times (T)}}{\text{Actual number of workstations (Na) x Cycle time (C)}}$$

$$\text{Efficiency} = \frac{11.35 \text{ mins / unit}}{(3)(4.2\text{mins / unit})} = \mathbf{.901}$$

Fixed Position Oriented Layout

Fixed-Position Layouts

- Typical of projects
- Fragile, bulky, heavy items
- Equipment, workers & materials brought to site
- Low equipment utilization
- Highly skilled labor
- Typically low fixed cost
- Often high variable costs

Hybrid (Cellular) Oriented Layout

Hybrid Layouts

- Cellular layouts
  - group dissimilar machines into work centers (called cells) that process families of parts with similar shapes or processing requirements
- Production flow analysis (PFA)
  - reorders part routing matrices to identify families of parts with similar processing requirements
- Flexible manufacturing system
  - automated machining and material handling systems which can produce an enormous variety of items
- Mixed-model assembly line (*Mainly for product based layouts*)
  - processes more than one product model in one line

Cellular Layouts

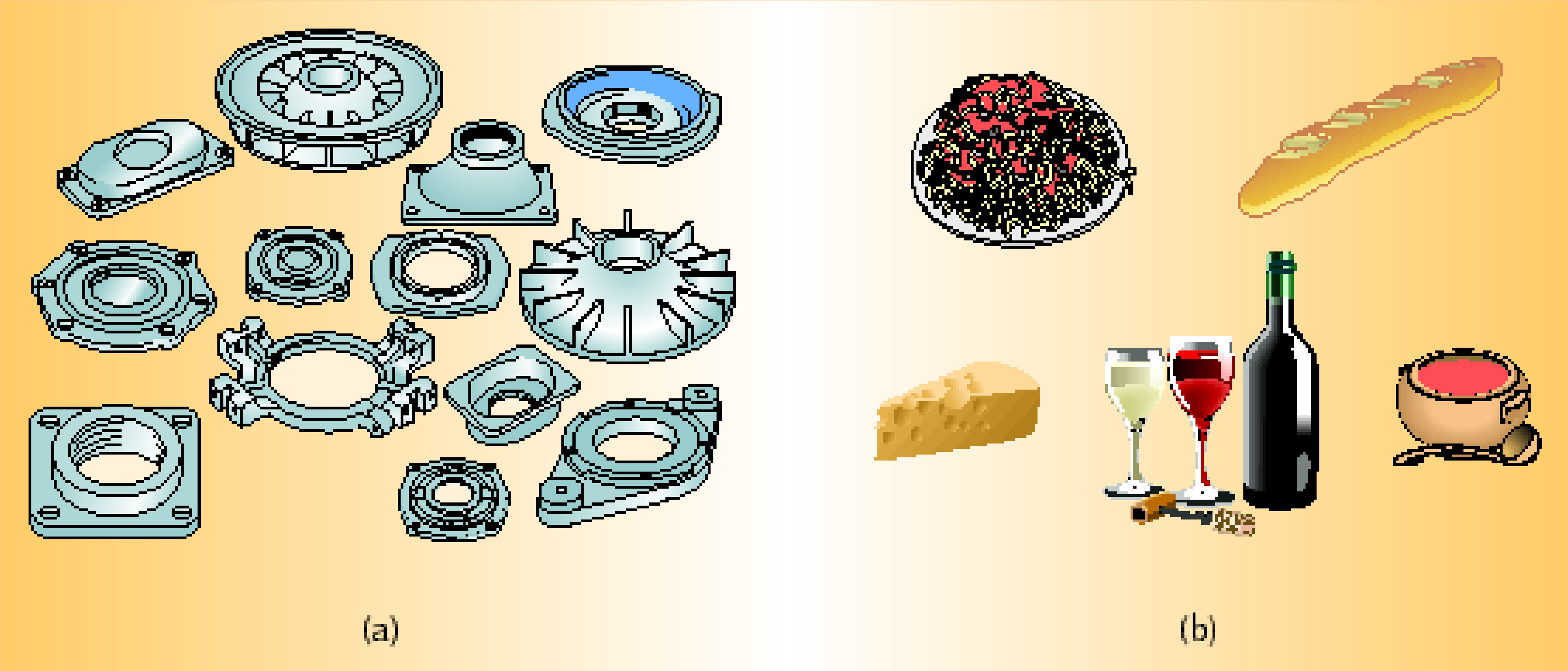
1. Identify families of parts with similar flow paths

2. Group machines into cells based on part families

3. Arrange cells so material movement is minimized

4. Locate large shared machines at point of use

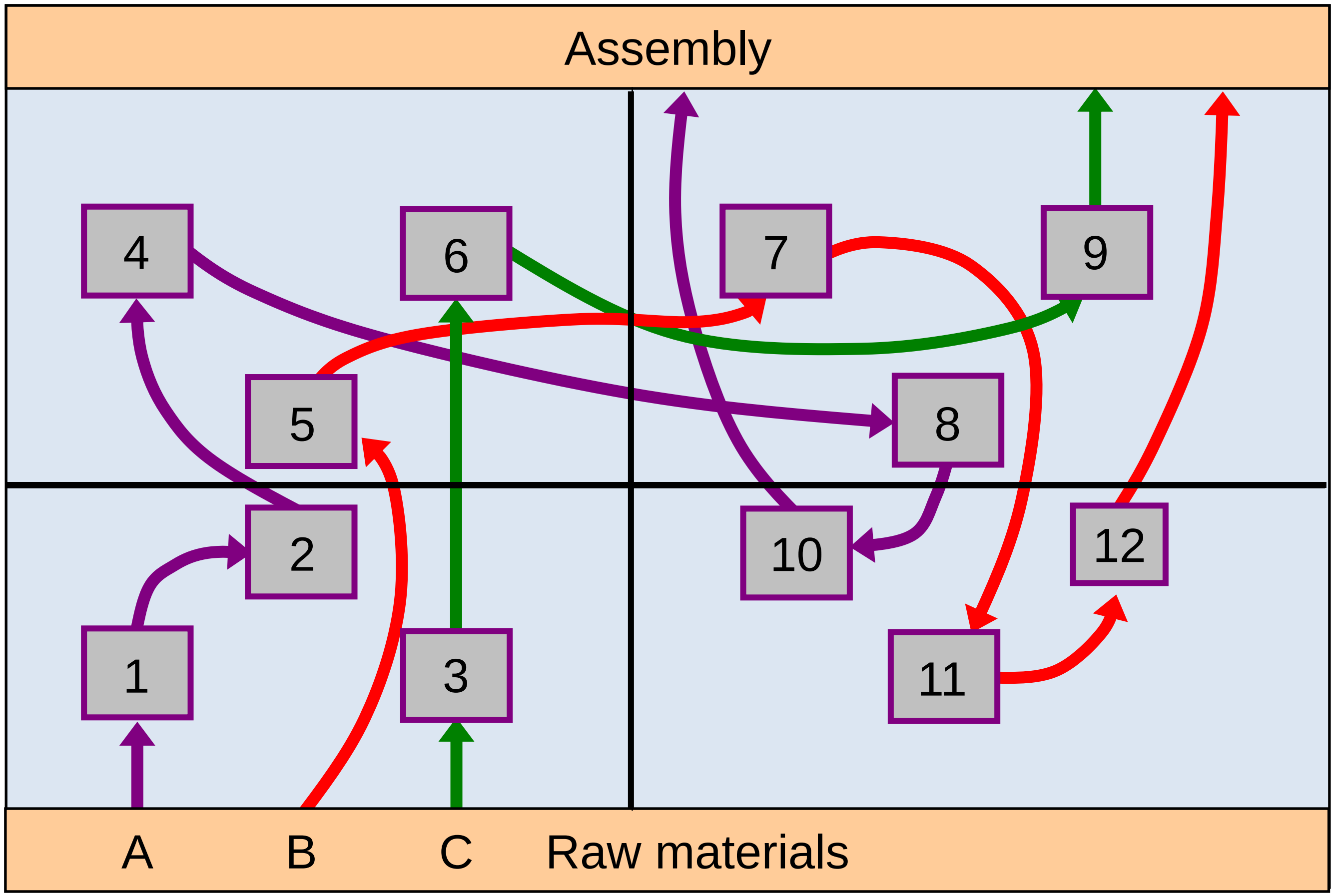
Parts Families



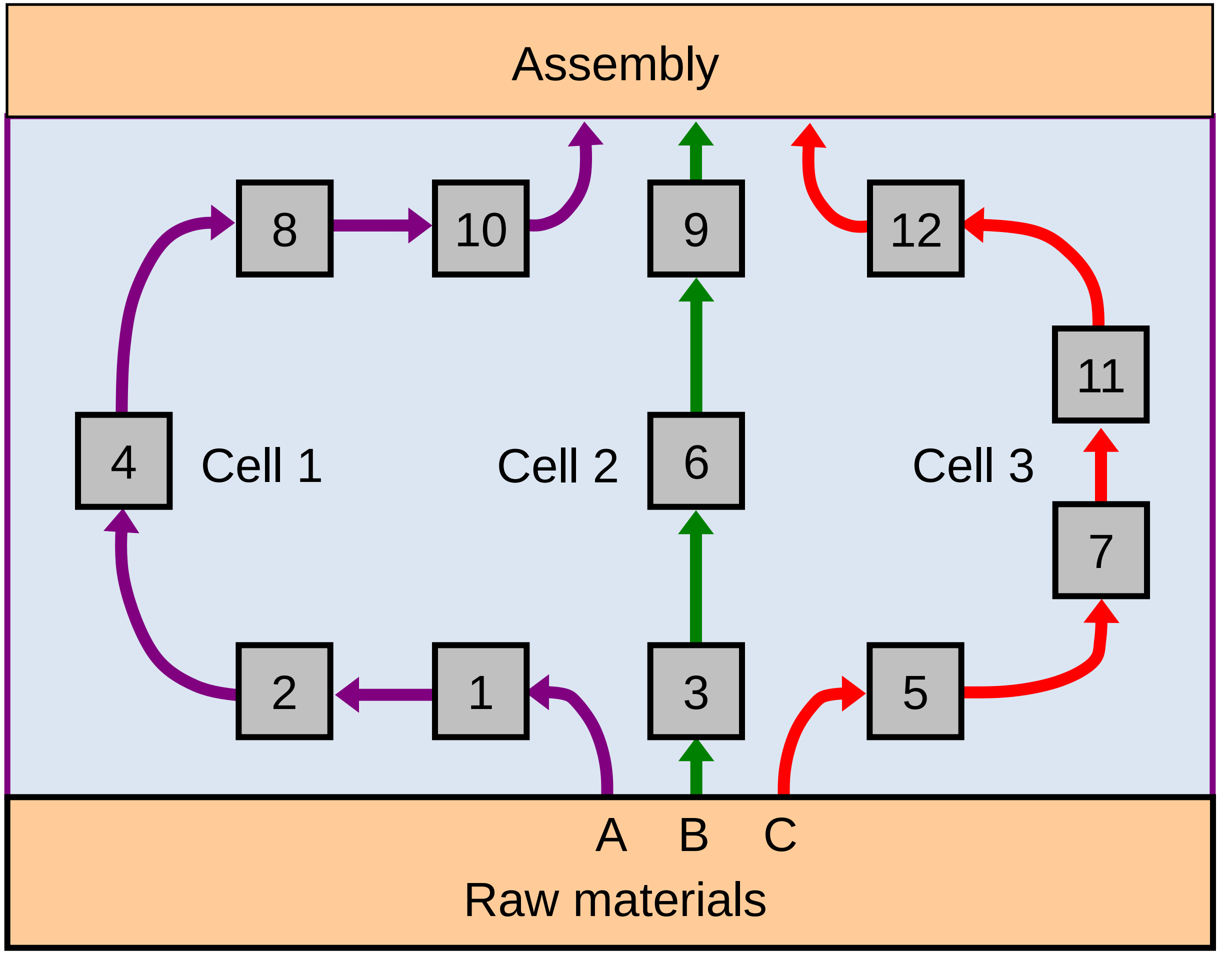
A family of similar parts

A family of related grocery items

Original Process Layout



Revised Cellular Layout



Part Routing Matrix

	Machines											
Parts	1	2	3	4	5	6	7	8	9	10	11	12
A	x	x		x				x		x		
B					x		x				x	x
C			x			x			x			
D	x	x		x				x		x		
E				x	x							x
F	x			x				x				
G			x			x			x			x
H							x				x	x

Reordered Routing Matrix

Parts	Machines											
	1	2	4	8	10	3	6	9	5	7	11	12
A	x	x	x	x	x							
D	x	x	x	x	x							
F	x		x	x								
C						x	x	x				
G						x	x	x				x
B									x	x	x	x
H										x	x	x
E							x		x			x

Parts	Machines 1	2	3	4	5	6	7	8	9	10	11	12
A	x	x		x				x		x		
B					x		x				x	x
C			x			x			x			
D	x	x		x				x		x		
E				x	x							x
F	x			x				x				
G			x			x			x			x
H							x				x	x

Parts	Machines 1	2	4	8	10	3	6	9	5	7	11	12
A	x	x	x	x	x							
D	x	x	x	x	x							
F	x		x	x								
C						x	x	x				
G						x	x	x				x
B									x	x	x	x
H										x	x	x
E							x		x			x

Cellular Layouts

- Advantages
  - Reduced material handling and transit time
  - Reduced setup time
  - Reduced work-in- process inventory
  - Better use of human resources
  - Easier to control
  - Easier to automate
- Disadvantages
  - Inadequate part families
  - Poorly balanced cells
  - Expanded training and scheduling of workers
  - Increased capital investment

Sample part-machine processing indicator matrix

$$
[a_{ij}] = \begin{array}{cc}
 & \begin{array}{ccccccc} \mathrm{M} & \mathrm{a} & \mathrm{c} & \mathrm{h} & \mathrm{i} & \mathrm{n} & \mathrm{e} \\ M_1 & M_2 & M_3 & M_4 & M_5 & M_6 & M_7 \end{array} \\
\begin{array}{cc} & P_1 \\ \mathrm{P} & P_2 \\ \mathrm{a} & P_3 \\ \mathrm{r} & P_4 \\ \mathrm{t} & P_5 \\ & P_6 \end{array} &
\left[\begin{array}{ccccccc}
1 & & & 1 & & 1 & \\
 & 1 & 1 & & 1 & & \\
 & & & 1 & & 1 & \\
 & 1 & 1 & & & & \\
 & & 1 & & & & 1 \\
 & 1 & & & 1 & & 1
\end{array}\right]
\end{array}
$$

$$
[a_{ij}] = \begin{array}{cc}
 & \begin{array}{ccccccc} M_1 & M_4 & M_6 & M_2 & M_3 & M_5 & M_7 \end{array} \\
\begin{array}{cc} & P_1 \\ \mathrm{P} & P_3 \\ \mathrm{a} & P_2 \\ \mathrm{r} & P_4 \\ \mathrm{t} & P_5 \\ & P_6 \end{array} &
\left[\begin{array}{ccc|cccc}
1 & 1 & 1 & & & & \\
 & 1 & 1 & & & & \\
\hline
1 & & & 1 & 1 & 1 & \\
 & & & 1 & 1 & & \\
 & & & & & 1 & 1 \\
 & & & 1 & & 1 & 1
\end{array}\right]
\end{array}
$$

$$
[a_{ij}] = \begin{array}{cc}
 & \begin{array}{ccccccc} \mathrm{M} & \mathrm{a} & \mathrm{c} & \mathrm{h} & \mathrm{i} & \mathrm{n} & \mathrm{e} \\ M_1 & M_4 & M_6 & M_2 & M_3 & M_5 & M_7 \end{array} \\
\begin{array}{cc} & P_1 \\ \mathrm{P} & P_3 \\ \mathrm{a} & P_2 \\ \mathrm{r} & P_4 \\ \mathrm{t} & P_5 \\ & P_6 \end{array} &
\left[\begin{array}{ccc|cccc}
2 & 3 & 1 & & & & \\
 & 1 & 2 & & & & \\
\hline
3 & & & 1 & 4 & 2 & \\
 & & & 2 & 1 & & \\
 & & & & & 1 & 2 \\
 & & & 1 & & 2 & 3
\end{array}\right]
\end{array}
$$

Clustering Approach for Hybrid Layout

- Rank order clustering
- Row and column masking

Rank Order Clustering Algorithm

Step 1: Assign binary weight $BW_j = 2^{m-j}$ to each column j of the part-machine processing indicator matrix.

Step 2: Determine the decimal equivalent *DE* of the binary value of each row *i* using the formula

$$DE_i = \sum_{j=1}^{m} 2^{m-j} a_{ij}$$

Step 3: Rank the rows in decreasing order of their *DE* values. Break ties arbitrarily. Rearrange the rows based on this ranking. If no rearrangement is necessary, stop; otherwise go to step 4.

Rank Order Clustering Algorithm

Step 4: For each rearranged row of the matrix, assign binary weight $BW_i = 2^{n-i}$.

Step 5: Determine the decimal equivalent of the binary value of each column *j* using the formula

$$DE_j = \sum_{i=1}^{m} 2^{n-i} a_{ij}$$

Step 6: Rank the columns in decreasing order of their *DE* values. Break ties arbitrarily. Rearrange the columns based on this ranking. If no rearrangement is necessary, stop; otherwise go to step 1.

Rank Order Clustering – **Example 6**

$$
\begin{array}{llccccccccc}
 & & M_1 & M_2 & M_3 & M_4 & M_5 & M_6 & M_7 & & \\
\text{Binary weight} & & 64 & 32 & 16 & 8 & 4 & 2 & 1 & & \text{Binary value} \\
 & P_1 & 1 & & & 1 & & 1 & & & 74 \\
 & P_2 & & 1 & 1 & & 1 & & & & 52 \\
[a_{ij}] = & P_3 & & & & 1 & & 1 & & & 10 \\
 & P_4 & & 1 & 1 & & & & & & 48 \\
 & P_5 & & & 1 & & & & 1 & & 17 \\
 & P_6 & & 1 & & & 1 & & 1 & & 37
\end{array}
$$

$$
[a_{ij}] = \begin{array}{l|ccccccc|r}
 & M_1 & M_2 & M_3 & M_4 & M_5 & M_6 & M_7 & \\
\text{Binary value} & 32 & 28 & 26 & 33 & 20 & 33 & 6 & \text{Binary weight} \\
\hline
P_1 & 1 & & & 1 & & 1 & & 32 \\
P_2 & & 1 & 1 & & 1 & & & 16 \\
P_4 & & 1 & 1 & & & & & 8 \\
P_6 & & 1 & & & 1 & & 1 & 4 \\
P_5 & & & 1 & & & & 1 & 2 \\
P_3 & & & & 1 & & 1 & & 1 \\
\hline
\end{array}
$$

$$
\begin{array}{llc|ccccccc|c}
 & & & M_4 & M_6 & M_1 & M_2 & M_3 & M_5 & M_7 & \\
\text{Binary weight} & & & 64 & 32 & 16 & 8 & 4 & 2 & 1 & \text{Binary value} \\
\hline
 & & P_1 & 1 & 1 & 1 & & & & & 112 \\
 & & P_2 & & & & 1 & 1 & 1 & & 14 \\
 & [a_{ij}] = & P_4 & & & & 1 & 1 & & & 12 \\
 & & P_6 & & & & 1 & & 1 & 1 & 11 \\
 & & P_5 & & & & & 1 & & 1 & 5 \\
 & & P_3 & 1 & 1 & & & & & & 96 \\
\hline
\end{array}
$$

$$
\begin{array}{lc|ccc|cccc|c}
 & & M_4 & M_6 & M_1 & M_2 & M_3 & M_5 & M_7 & \\
\text{Binary value} & & 48 & 48 & 32 & 14 & 12 & 10 & 3 & \text{Binary weight} \\
\cline{3-9}
 & P_1 & 1 & 1 & 1 & & & & & 32 \\
 & P_3 & 1 & 1 & & & & & & 16 \\
\cline{3-9}
[a_{ij}] = & P_2 & & & & 1 & 1 & 1 & & 8 \\
 & P_4 & & & & 1 & 1 & & & 4 \\
 & P_6 & & & & 1 & & 1 & 1 & 2 \\
 & P_5 & & & & & & & 1 & 1 \\
\cline{3-9}
\end{array}
$$

		M_4	M_6	M_1	M_2	M_3	M_5	M_7	
Binary value		48	48	32	14	12	10	3	Binary weight
	P_1	1	1	1					32
	P_3	1	1						16
$[a_{ij}] =$	P_2				1	1	1		8
	P_4				1	1			4
	P_6				1		1	1	2
	P_5							1	1

Row and Column Masking Algorithm

Step 1: Draw a line through the first row. Select any 1 entry in the matrix through which there is only one line.

Step 2: If the entry has a horizontal line, go to step 2a. If the entry has a vertical line, go to step 2b.

Step 2a: Draw a vertical line through the column in which this 1 entry appears. Go to step 3.

Step 2b: Draw a horizontal line through the row in which this 1 entry appears. Go to step 3.

Step 3:If there are any 1 entries with only one line through them, select any one and go to step 2. Repeat until there are no such entries left. Identify the corresponding machine cell and part family. Go to step 4.

Step 4: Select any row through which there is no line. If there are no such rows, STOP. Otherwise draw a horizontal line through this row, select any 1 entry in the matrix through which there is only one line and go to Step 2.

R&CM Algorithm – **Example 7**

$$
[a_{ij}] = \begin{array}{cc}
 & \begin{array}{ccccccc} \text{M} & \text{a} & \text{c} & \text{h} & \text{i} & \text{n} & \text{e} \\ M_1 & M_2 & M_3 & M_4 & M_5 & M_6 & M_7 \end{array} \\
\begin{array}{cc} & P_1 \\ \text{P} & P_2 \\ \text{a} & P_3 \\ \text{r} & P_4 \\ \text{t} & P_5 \\ & P_6 \end{array} &
\left[\begin{array}{ccccccc}
1 & & & 1 & & 1 & \\
 & 1 & 1 & & 1 & & \\
 & & & 1 & & 1 & \\
 & 1 & 1 & & & & \\
 & & 1 & & & & 1 \\
 & 1 & & & 1 & & 1
\end{array}\right]
\end{array}
$$

$$[a_{ij}] = \begin{array}{cc} & \begin{array}{ccccccc} \text{M} & \text{a} & \text{c} & \text{h} & \text{i} & \text{n} & \text{e} \\ M_1 & M_2 & M_3 & M_4 & M_5 & M_6 & M_7 \end{array} \\ \begin{array}{cc} & P_1 \\ \text{P} & P_2 \\ \text{a} & P_3 \\ \text{r} & P_4 \\ \text{t} & P_5 \\ & P_6 \end{array} & \begin{bmatrix} 1 & & & 1 & & 1 & \\ & 1 & 1 & & 1 & & \\ & & & 1 & & 1 & \\ & 1 & 1 & & & & \\ & & 1 & & & & 1 \\ & 1 & & & 1 & & 1 \end{bmatrix} \end{array}$$

$$[a_{ij}] = \begin{array}{ccc}
 & & \begin{array}{ccccccc} \text{M} & \text{a} & \text{c} & \text{h} & \text{i} & \text{n} & \text{e} \\ M_1 & M_2 & M_3 & M_4 & M_5 & M_6 & M_7 \end{array} \\
\begin{array}{c} \\ \text{P} \\ \text{a} \\ \text{r} \\ \text{t} \\ \\ \end{array} & \begin{array}{c} P_1 \\ P_2 \\ P_3 \\ P_4 \\ P_5 \\ P_6 \end{array} & \begin{bmatrix} 1 & & & 1 & & 1 & \\ & 1 & 1 & & 1 & & \\ & & & 1 & & 1 & \\ & 1 & 1 & & & & \\ & & 1 & & & & 1 \\ & 1 & & & 1 & & 1 \end{bmatrix}
\end{array}$$

R&CM Algorithm - Solution

$$
[a_{ij}] = \begin{array}{ccc}
 & & \begin{array}{ccc|cccc} \mathrm{M} & \mathrm{a} & \mathrm{c} & \mathrm{h} & \mathrm{i} & \mathrm{n} & \mathrm{e} \\ M_1 & M_4 & M_6 & M_2 & M_3 & M_5 & M_7 \end{array} \\
\begin{array}{c} \\ \mathrm{P} \\ \mathrm{a} \\ \mathrm{r} \\ \mathrm{t} \\ \\ \end{array} &
\begin{array}{c} P_1 \\ P_3 \\ P_2 \\ P_4 \\ P_5 \\ P_6 \end{array} &
\left[\begin{array}{ccc|cccc}
1 & 1 & 1 & & & & \\
 & 1 & 1 & & & & \\
\hline
 & & & 1 & 1 & 1 & \\
 & & & 1 & 1 & & \\
 & & & & 1 & & 1 \\
 & & & 1 & & 1 & 1
\end{array}\right]
\end{array}
$$

Servicescapes in Layout

Servicescape is a model developed by Booms and Bitner to emphasize the impact of physical environment where a service process takes place.

Aim is to explain behavior of people within the service environment with a view to designing environments that accomplish organisational goals in terms of achieving desired behavioural responses. EX: For consumers visiting a service or retail store, the service environment is the first aspect of the service that is perceived by the customer and it is at this stage that consumers are likely to form impressions of the level of service they will receive.

Source: Booms, BH; Bitner, MJ (1981). "Marketing strategies and organisation structures for service firms". In Donnelly, J; George, WR. *Marketing of Services*. Chicago, IL: American Marketing Association

The **servicescape** is usually playing an important role.

The behavior of the customers and their satisfaction to the service is related to the **servicescape**.

As we have mentioned that providing a high quality **servicescape** is an important factor to gain a competitive advantage.

Few examples


EXIT


Thank You!