Layout design I.

Chapter 6

Basic layout types

Systematic layout planning procedure

Computerized layout planning

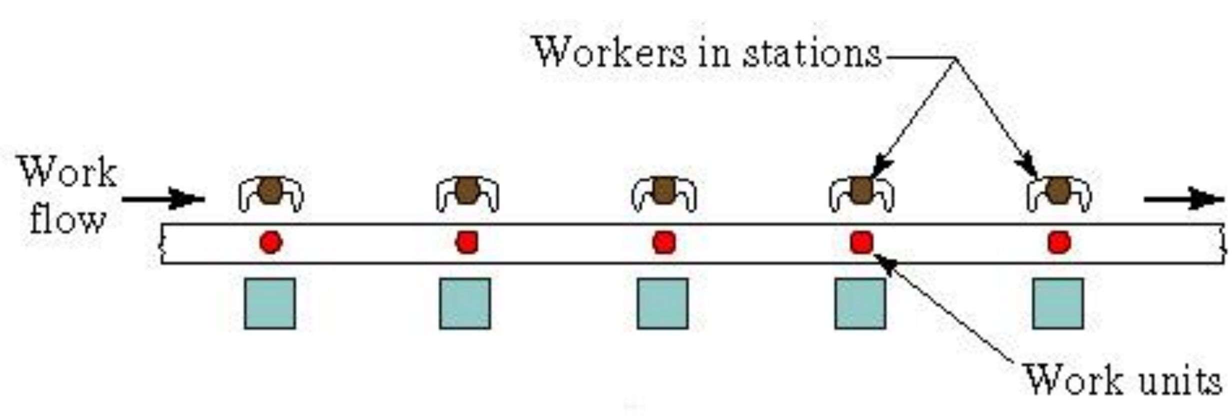
Algorithm classification

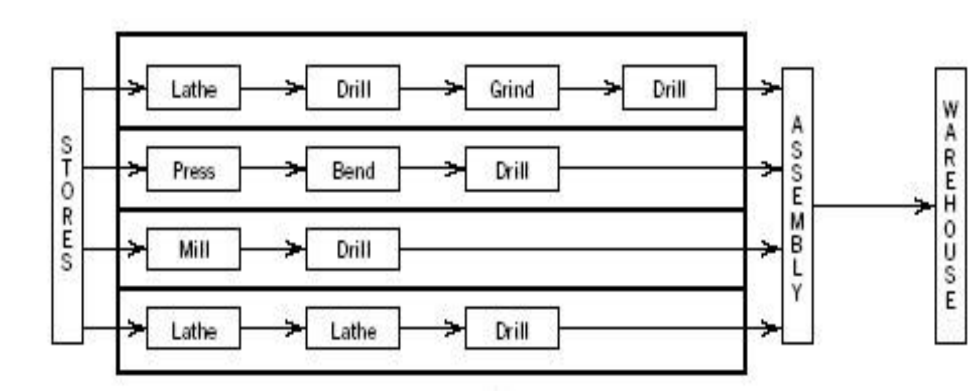
- Evaluation of the layout
- Construction of the layout

Basic layout types

- Types of layout designs:
  - **Block layout**
    - Shows relative locations and sizes of the departments
  - **Detailed layout**
    - Show the exact locations of all the equipment, workstations, storage within the departments
- Types of planning departments
  - Fixed product layout
  - Product layout
  - Group layout
  - Process layout

Product Layout





Product:

- Standardized
- Large stable demand

Layout:

- Combines all workstations required to produce the product

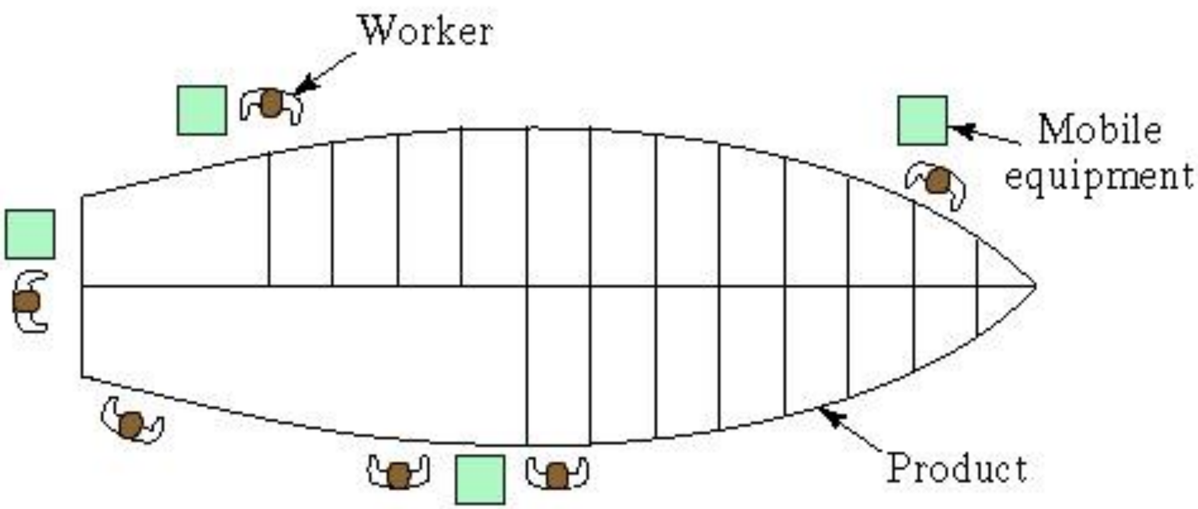
Product Layout

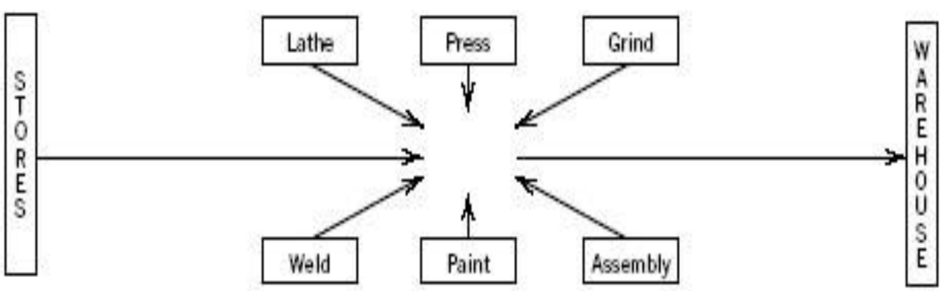
The product flows through an assembly line while the personnel and equipment movements are limited

- Advantages
  - Smooth, simple, logical and direct flow
  - High Production Rate
  - Low cost per unit cost
  - High machine/worfkforce utilization
  - Lower material handling costs
  - Less personnel skill is required
  - Lower Work-In-Process Inventory (WIP)

- Disadvantages
  - High machine utilization is risky
  - Process performance depends on the bottleneck operation
  - May not be flexible enough for product design, volume changes
  - Decreased employee motivation
  - Huge investment is required

Fixed Product Layout





Product:

- Physically large
- Awkward to move
- Low sporadic demand

Layout:

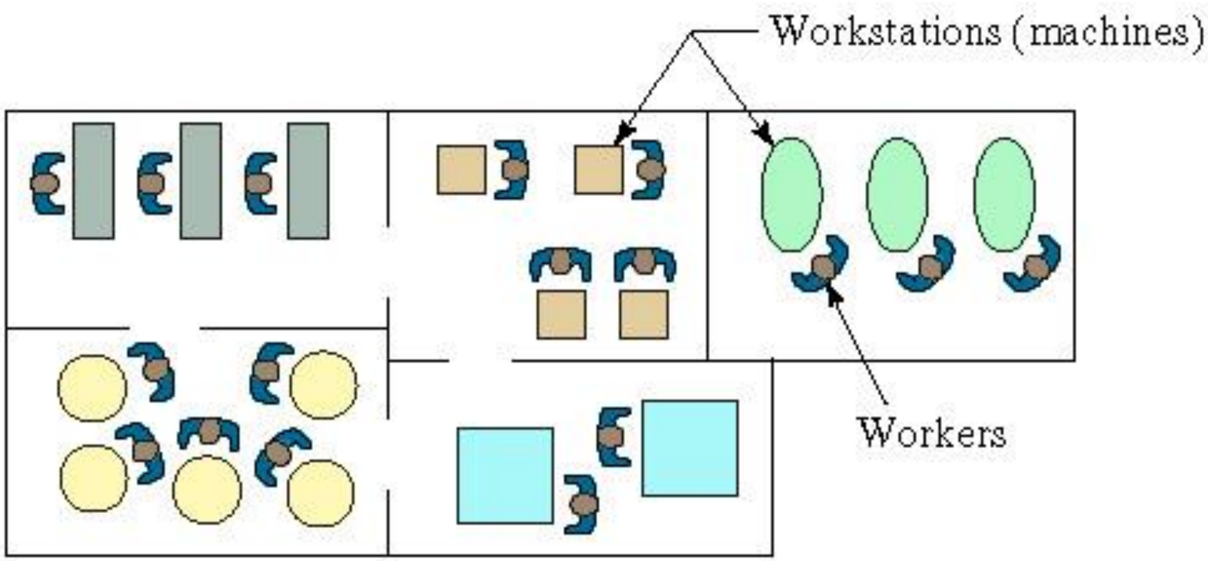
- Combines all workstations required to produce the product with the area required for staging the product

Fixed Product Layout

Production is executed at a fixed location; materials, equipment, and personnel flow into this location.

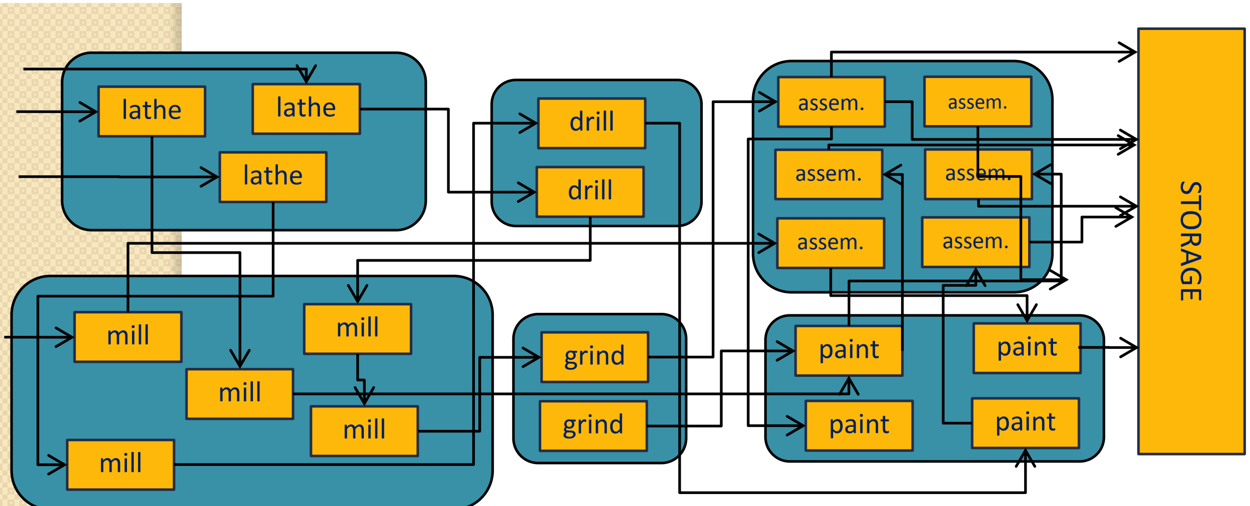
- Advantages
  - Material movement is reduced
  - An individual can complete the whole process
  - Job enrichment opportunities
  - Highly flexible; can accommodate any changes in design
- Disadvantages
  - Personal and equipment movement is increased
  - Risk of duplication of equipment
  - Requires greater worker skills
  - Not suitable for high production volumes
  - Close control and coordination in scheduling

Process Layout



Product:

- Great variety
- Intermittent demand



Layout:

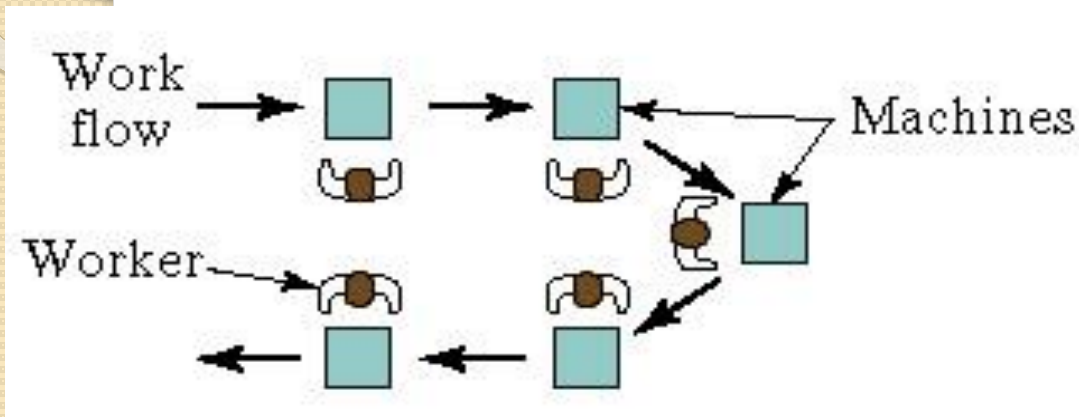
- Combines identical workstations into departments
- Combines similar departments

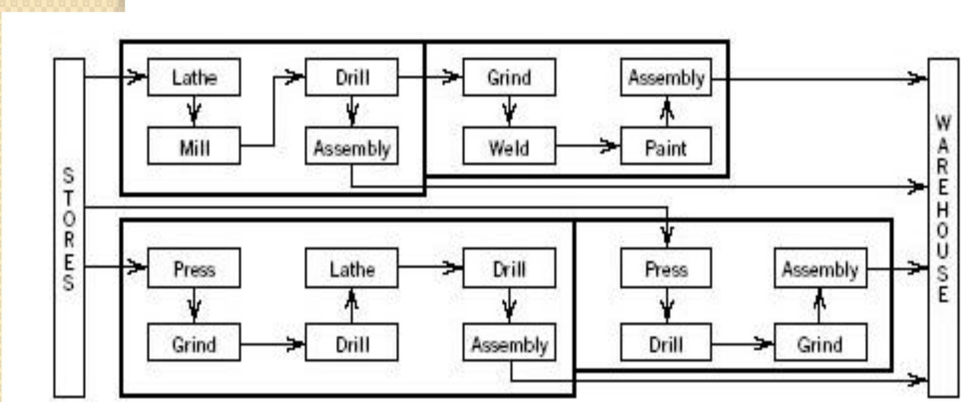
Process Layout

Similar/Same processes are grouped together.

- Advantages
  - Increased machine utilization
  - Flexible in allocating personnel and equipment
  - Robust against machine breakdowns
  - Robust against design, volume changes
  - Specialized supervision is possible
- Disadvantages
  - Material handling requirements are increased
  - Increased WIP
  - Longer production lines
  - Difficult to schedule the jobs
  - Higher skills are required
  - Difficult to analyze the process performance

Product Family - Group Layout





Product:

- Capable of being grouped into families of similar parts

Layout:

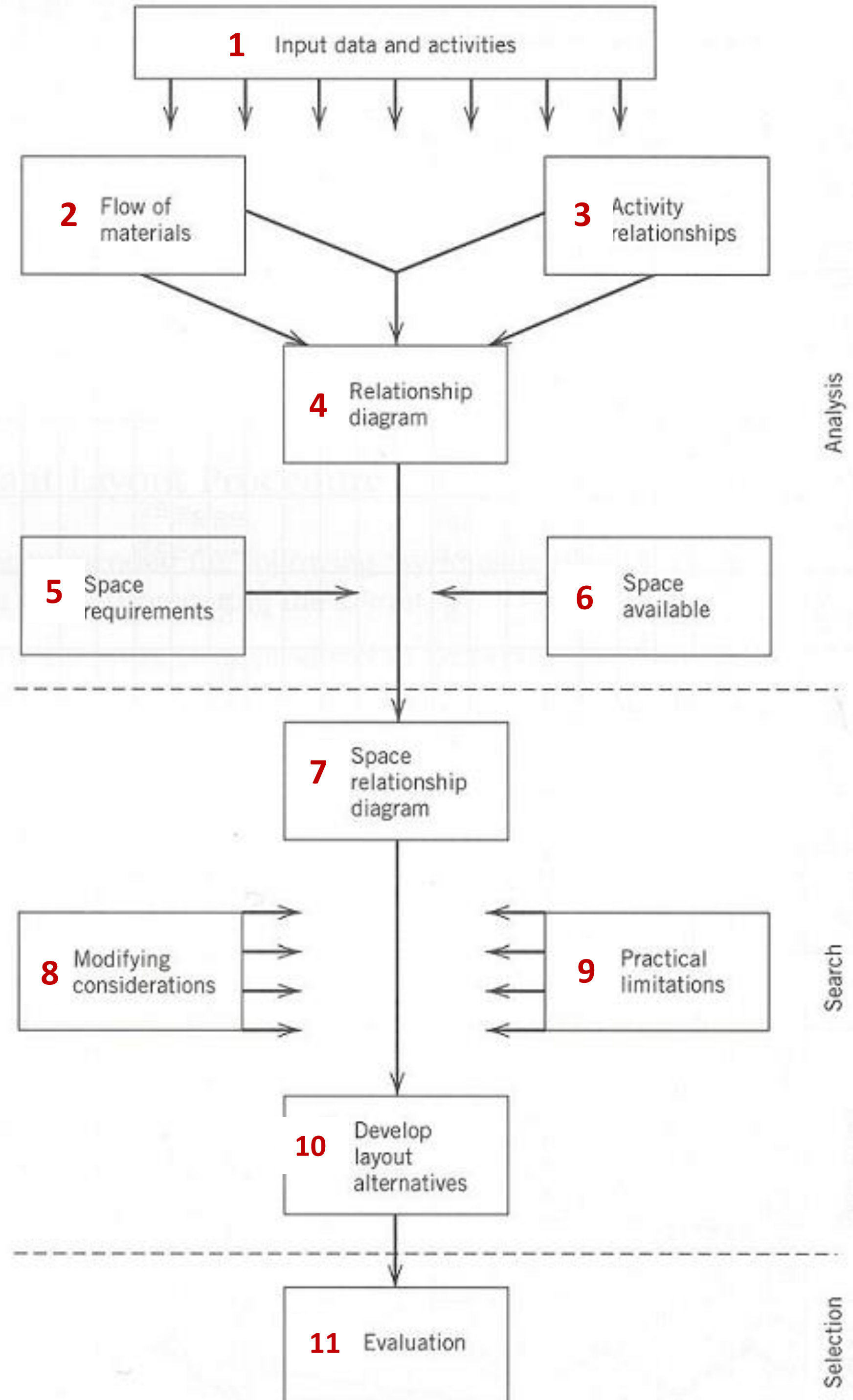
- Combine all workstations required to produce the family of products

Product Family - Group Layout

Product Family Layouts are like a combination of Product Layouts and Process Layouts

- Advantages
  - Combines benefits of product and process layouts
  - Higher machine utilization
  - Smoother flow lines and shorter distance
  - Team atmosphere
- Disadvantages
  - General supervision required
  - Greater labor skills requirement
  - Balancing manufacturing cells are difficult and unbalanced cells may increase WIP

Systematic layout planning procedure



1. Input data and activities

- Bill of materials
- Operation process chart

BILL OF MATERIALS

Company T. W., Inc. Prepared by J. A.
Product Air Flow Regulator Date

Level	Part No.	Part Name	Drwg. No.	Quant./ Unit	Make or Buy	Comm
0	0021	Air flow regulator	0999	1	Make	
1	1050	Pipe plug	4006	1	Buy	
1	6023	Main assembly	—	1	Make	
2	4250	Lock nut	4007	1	Buy	
2	6022	Body assembly	—	1	Make	
3	2200	Body	1003	1	Make	
3	6021	Plunger assembly	—	1	Make	
4	3250	Seat ring	1005	1	Make	
4	3251	O-ring	—	1	Buy	
4	3252	Plunger	1007	1	Make	
4	3253	Spring	—	1	Buy	
4	3254	Plunger housing	1009	1	Make	
4	3255	O-ring	—	1	Buy	
4	4150	Plunger retainer	1011	1	Make	

Figure 2.8 Bill of materials for an air flow regulator.

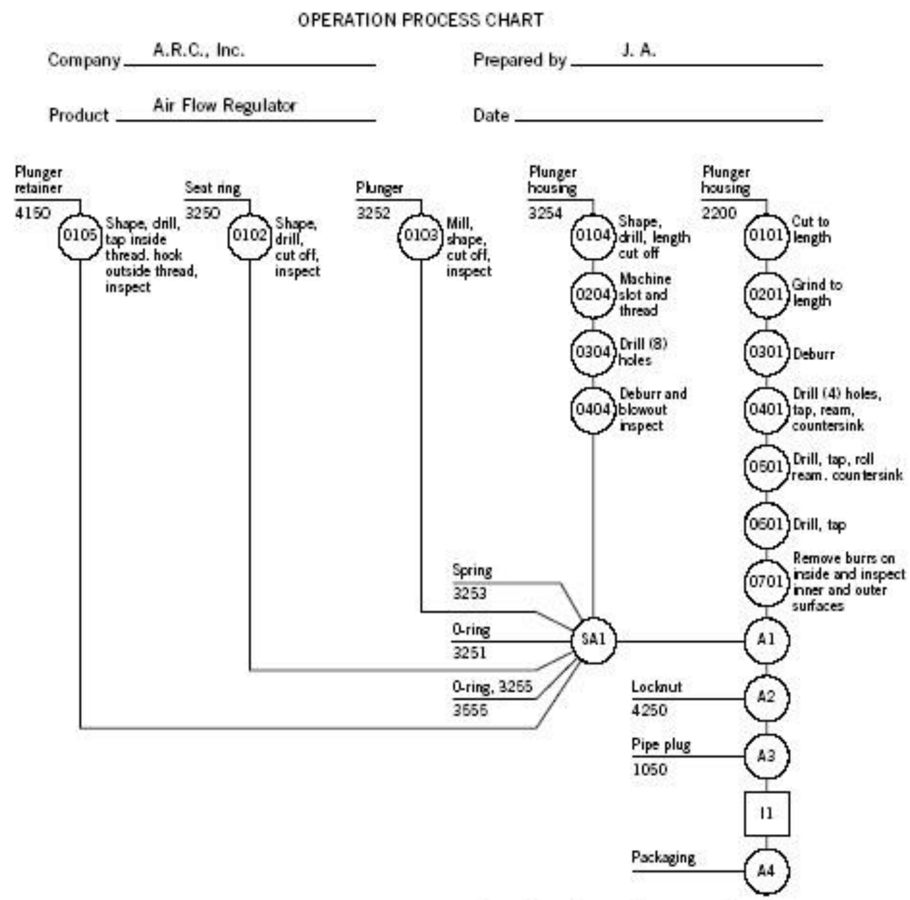
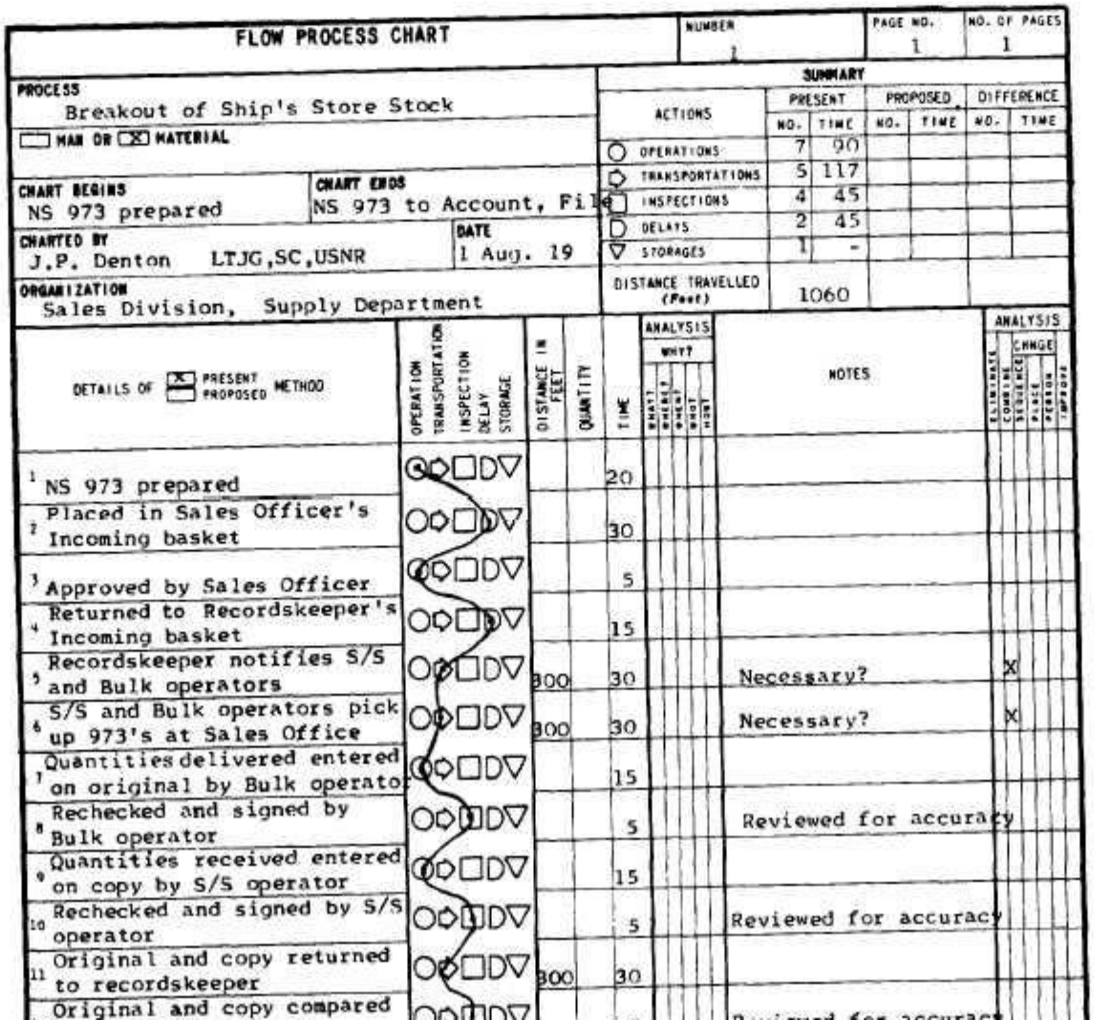


Figure 2.13 Operation process chart for the air flow regulator.

2. Flow of materials

- Flow process chart



FLOW PROCESS CHART

NUMBER 1 | PAGE NO. 1 | NO. OF PAGES 1

PROCESS: Breakout of Ship's Store Stock

☐ MAN OR ☒ MATERIAL

CHART BEGINS: NS 973 prepared

CHART ENDS: NS 973 to Account, File

CHARTED BY: J.P. Denton LTJG,SC,USNR

DATE: 1 Aug. 19

ORGANIZATION: Sales Division, Supply Department

SUMMARY

ACTIONS	PRESENT NO.	PRESENT TIME	PROPOSED NO.	PROPOSED TIME	DIFFERENCE NO.	DIFFERENCE TIME
OPERATIONS	7	90				
TRANSPORTATIONS	5	117				
INSPECTIONS	4	45				
DELAYS	2	45				
STORAGES	1	-				
DISTANCE TRAVELLED (Feet)	1060					

DETAILS OF ☒ PRESENT ☐ PROPOSED METHOD

	DETAILS	DISTANCE IN FEET	QUANTITY	TIME	NOTES
1	NS 973 prepared			20	
2	Placed in Sales Officer's Incoming basket			30	
3	Approved by Sales Officer			5	
4	Returned to Recordskeeper's Incoming basket			15	
5	Recordskeeper notifies S/S and Bulk operators	300		30	Necessary?
6	S/S and Bulk operators pick up 973's at Sales Office	300		30	Necessary?
7	Quantities delivered entered on original by Bulk operato			15	
8	Rechecked and signed by Bulk operator			5	Reviewed for accuracy
9	Quantities received entered on copy by S/S operator			15	
10	Rechecked and signed by S/S operator			5	Reviewed for accuracy
11	Original and copy returned to recordskeeper	300		30	
	Original and copy compared				

- From-to chart

	Stores	Milling	Turning	Press	Plate	Assembly	Warehouse
Stores	–	24	12	16	1	8	–
Milling	–	–	–	–	14	3	1
Turning	–	3	–	–	8	–	1
Press	–	–	–	–	3	1	1
Plate	–	3	2	–	–	4	3
Assembly	2	–	–	–	–	–	7
Warehouse	–	–	–	–	–	–	–

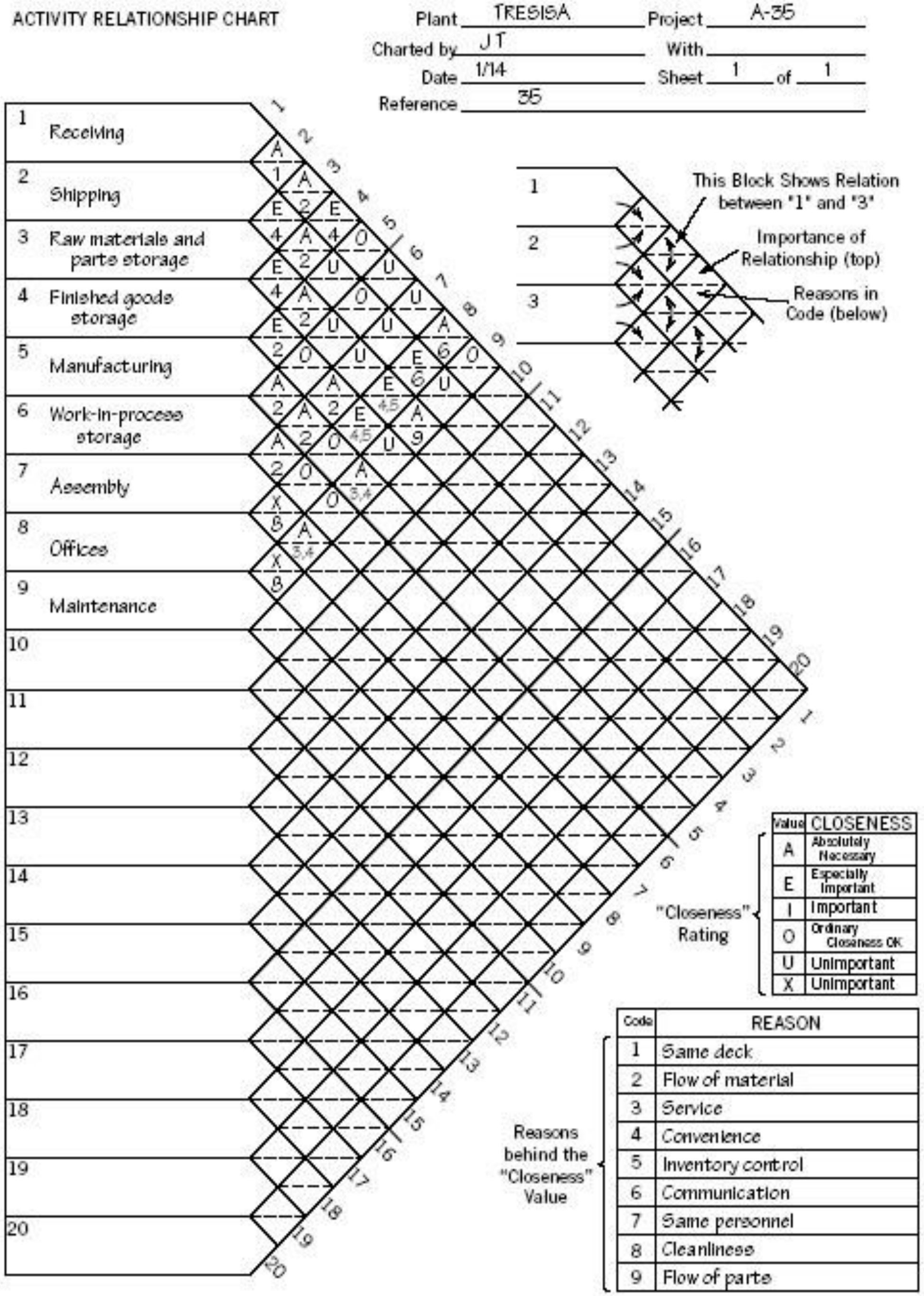


Figure 6.4 Activity relationship chart.

3. Activity relationships

- Relationship Chart measures the flows qualitatively using the **closeness relationships values**

Rating	CLOSENESS VALUES
A	Absolutely Necessary
E	Especially Important
I	Important
O	Ordinary Closeness
U	Unimportant
X	Undesirable

4. Relationship diagram

- The relationship diagram positions activities spatially
  - Proximities reflect the relationship between pairs of activities
  - Usually two dimensional

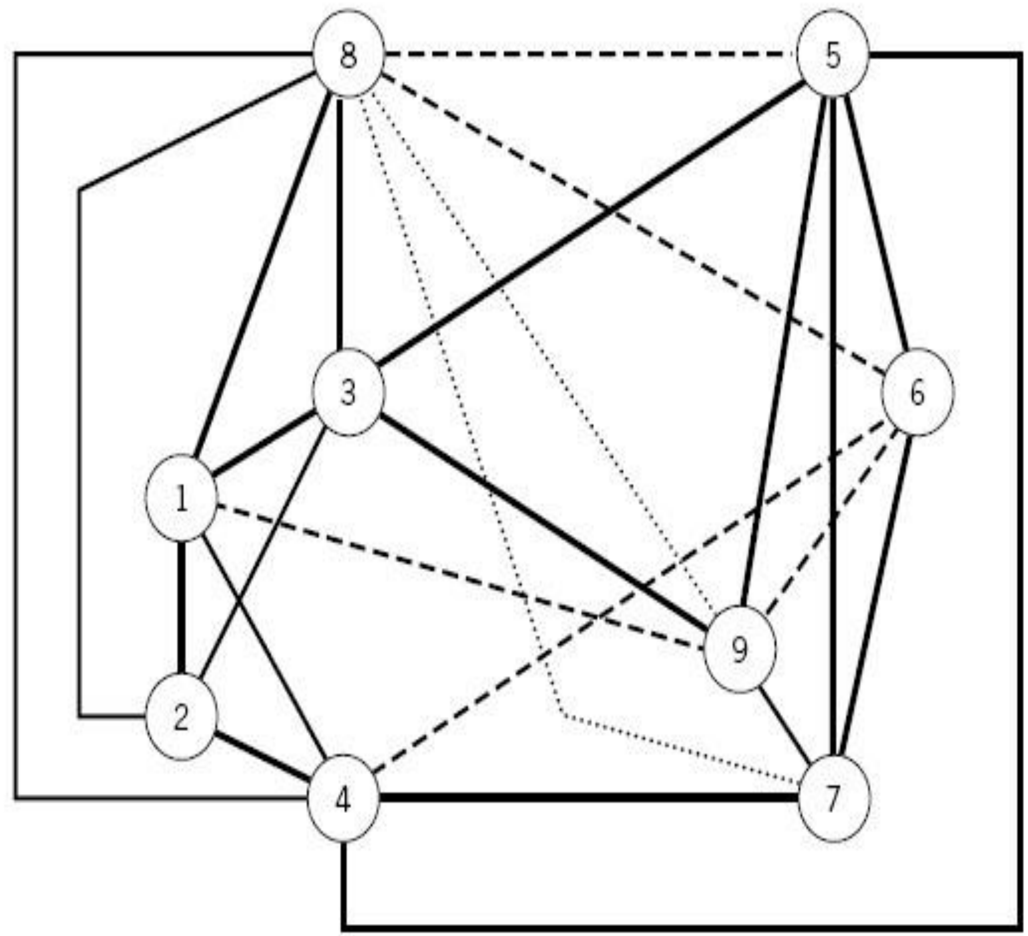


Figure 6.5 Relationship diagram.

5. Space requirements

- Required departmental area

Depart.	Function	Area (ft^2)
D1	Receiving	12,000
D2	Milling	8,000
D3	Press	6,000
D4	Screw machine	12,000
D5	Assembly	8,000
D6	Plating	12,000
D7	Shipping	12,000

7. Space relationship diagram

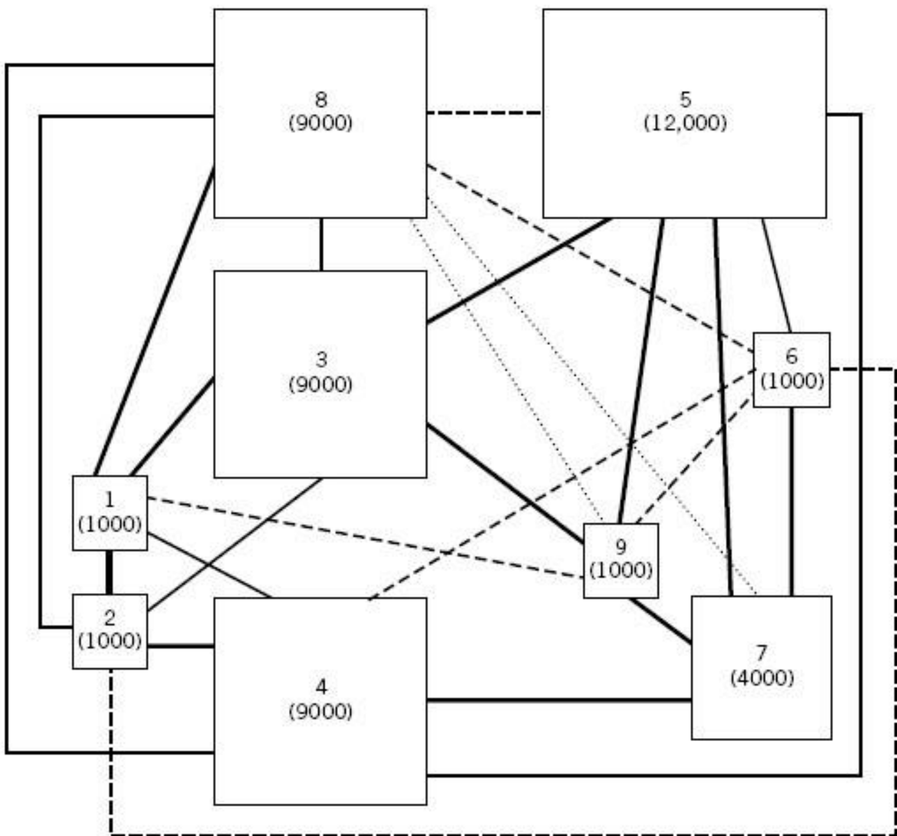
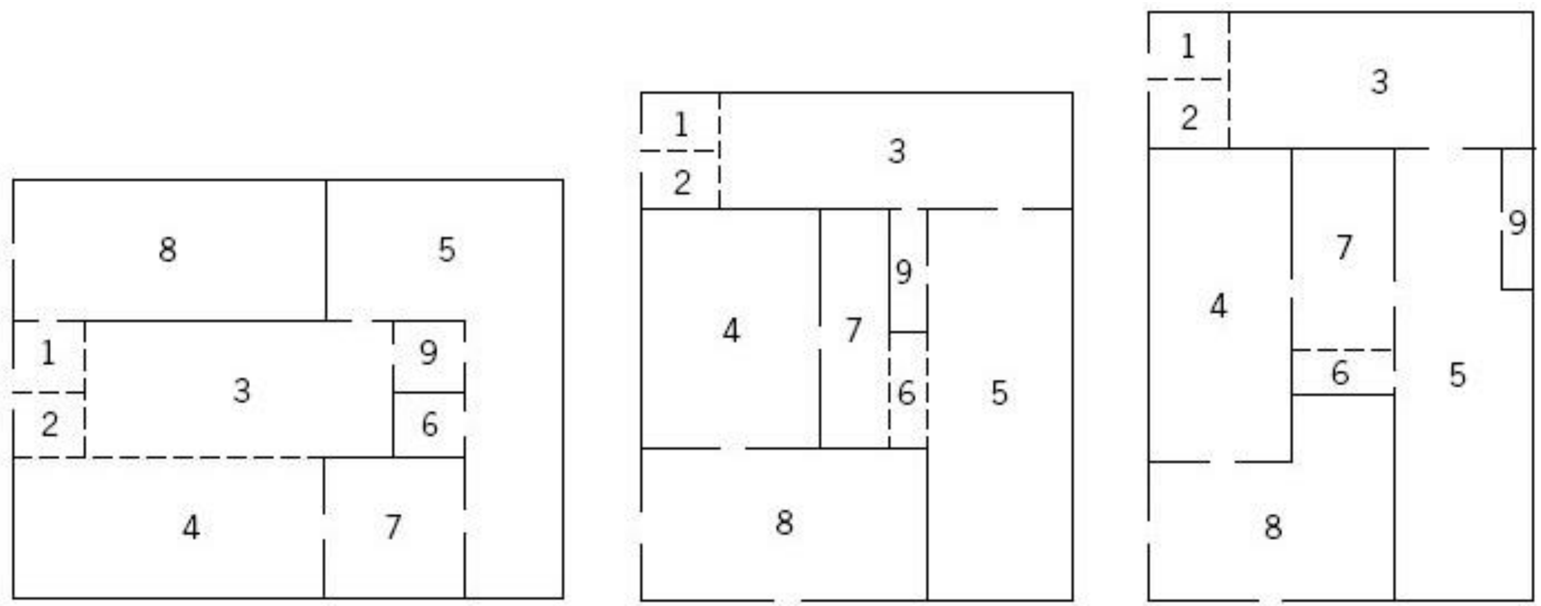


Figure 6.6 Space relationship diagram.

- Space relationship diagram combines space requirements with relationship diagram

10. Layout alternatives



- Conversion of a space relationship diagram into several feasible alternative **block layouts**
  - not a mechanical process
  - importance of intuition, judgment and experience

Computerized Layout Planning

- Computers can greatly aid the facility layout process.

- Designer must interact with multiple design databases and provide the integration between them to translate information and ensure consistency.

- Decision aids for block layout planning
  - Information required
  - Algorithm classification
  - Layout software:
    - "Classical" layout programs
      - Craft, Corelap, Aldep, and Planet
    - "Newer" layout programs
      - M-Craft, LayOpt, FactoryPlan

Computerized Layout Planning

Information in layout planning

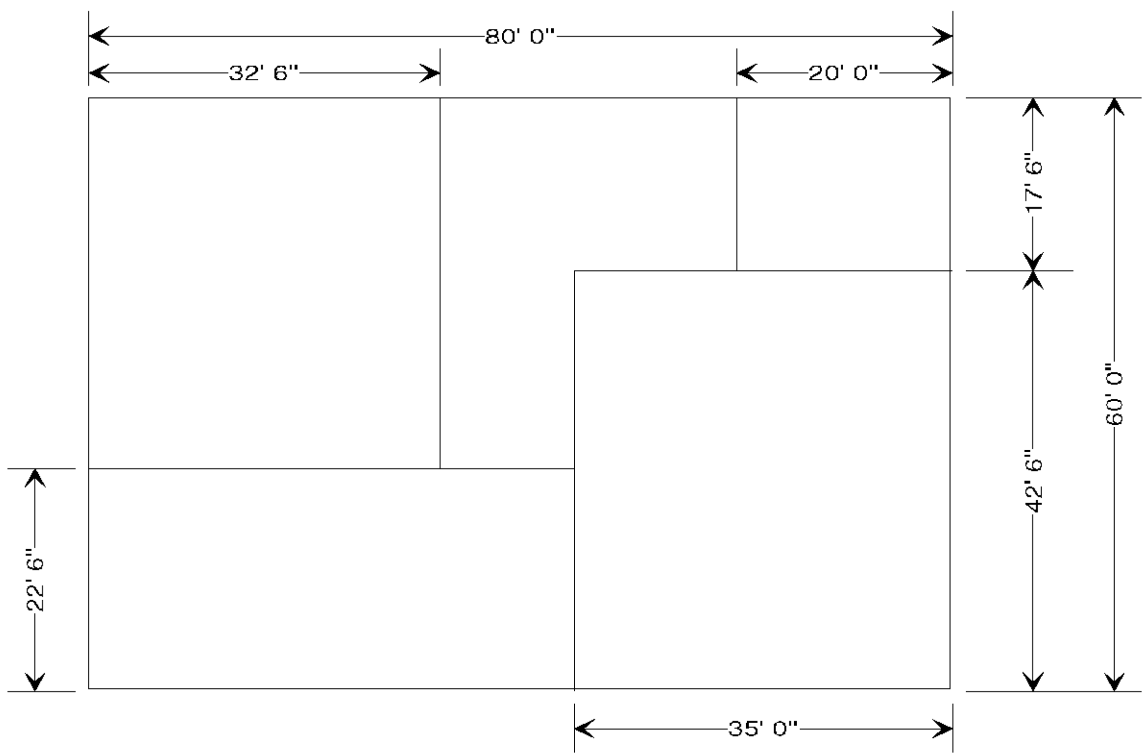
- Quantitative information
  - For ex. space required for an activity, cost information, distances between the departments, total flow between two activities
- Qualitative information
  - For ex. preferences of the designer, activity relationship chart
- Graphical information
  - Drawing of the block plan

- Key element of computerized layout planning is the representation and manipulation of these three types of information.
  - **Graphical representation** is most challenging.   A method suitable for display is not suitable for manipulation and vice-versa.

Computerized Layout Planning

Graphical representation

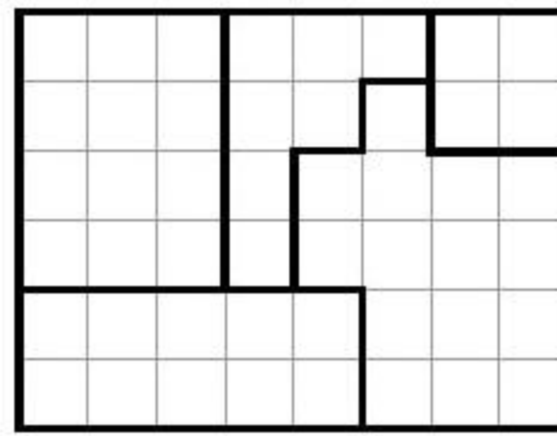
"Points and lines" representation is not convenient for analysis



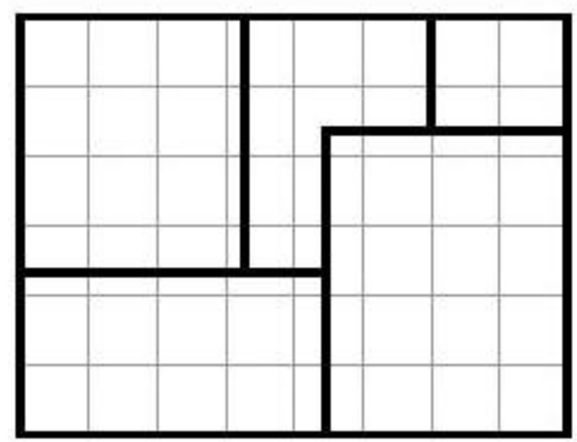
Computerized Layout Planning

Graphical representation

- Discrete
  - Grid size and computational burden



- Continuous
  - Rectangular buildings and departmental shapes



Computerized Layout Planning

Graphical representation

- Most procedures employ a "unit area square" representation as an approximation

  Space available and space required for each activity are expressed as *an* ***integer multiple of the unit area.***

- **Unit Square Area** approximation can also be represented by a two dimensional array or matrix of numbers
  - Easy to manipulate (*e.g.*, determine adjacency) but difficult to visually interpret

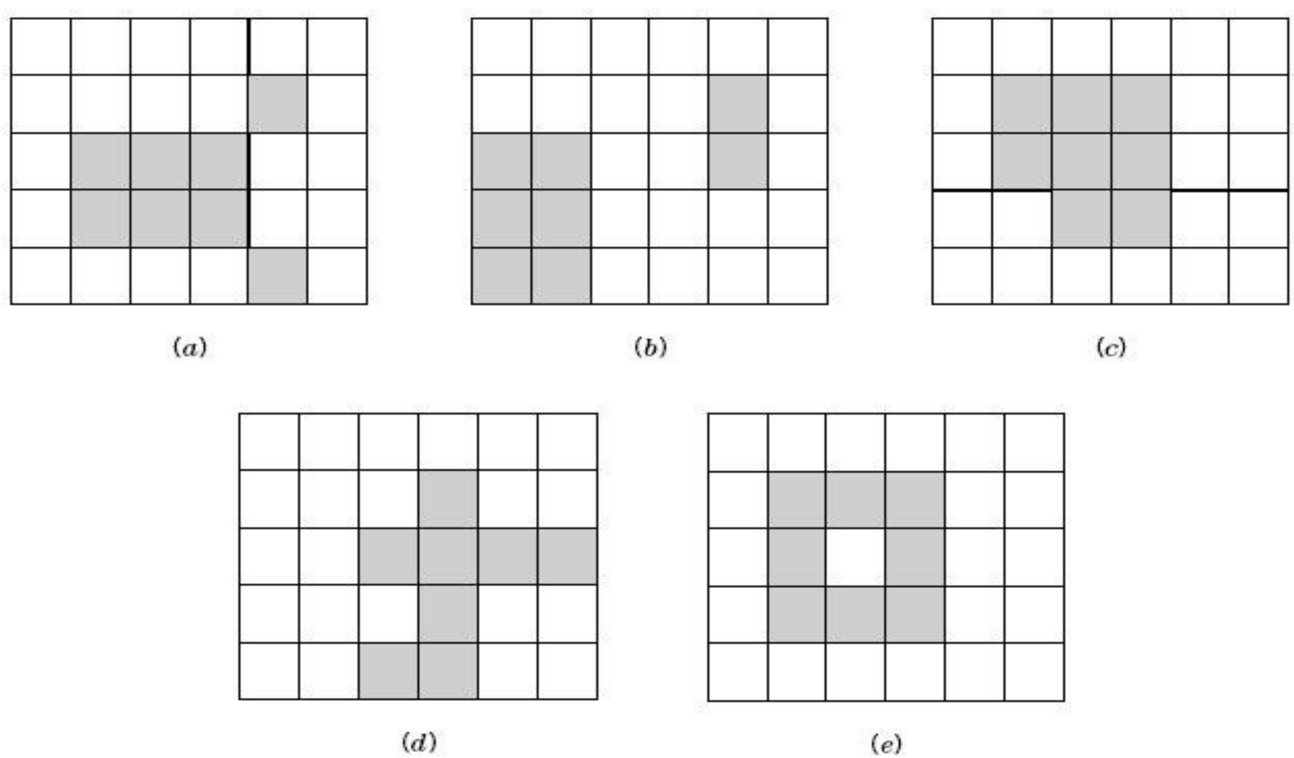
1	1	1	2	2	2	3	3
1	1	1	2	2	4	3	3
1	1	1	2	4	4	4	4
1	1	1	2	4	4	4	4
5	5	5	5	5	4	4	4
5	5	5	5	5	4	4	4

1	1	1	2	2	2	3	3
1	1	1	2	2	4	3	3
1	1	1	2	4	4	4	4
1	1	1	2	4	4	4	4
5	5	5	5	5	4	4	4
5	5	5	5	5	4	4	4

Computerized Layout Planning

Graphical representation

- department cannot be split
  - Any grid assigned to a department must be "reachable" form any other such grid
- enclosed void (atrium)



Layout Design - Algorithmic approaches

- Input data
  - Qualitative data - relationships (Relationship chart)
    - Subjective
    - May take long time to prepare
  - Quantitative data - flow data (From-to chart)
    - Objective
    - Can be prepared by computer
  - Both

- Three concepts:
  - **Layout Improvement**
    - Start with an initial layout and improve through incremental changes
  - **Layout Construction**
    - Develop a layout from scratch
      - Dimensions are given
      - No dimensions - "green field"
  - **Layout Evaluation**

Layout Evaluation

An algorithm needs to distinguish between "good" layouts and "bad" ones

- Minimize the total cost/traveling/load etc:

$$\min z = \sum_{i=1}^{m} \sum_{j=1}^{m} f_{ij} c_{ij} d_{ij}$$

- Maximize the total relationship:

$$\max z = \sum_{i=1}^{m-1} \sum_{j=i+1}^{m} f_{ij} x_{ij}$$

- Maximize the total satisfaction (Prioritization Matrix)

Layout Evaluation

Adjacency Based Scoring

- Adjacency-based scoring is based on the relationship chart and relationship diagram

$$\max z = \sum_{i=1}^{m-1} \sum_{j=i+1}^{m} f_{ij} x_{ij}$$

***m**:* number of departments

x_{ij}: *1* if ***i*** and ***j*** are adjacent, *0* otherwise

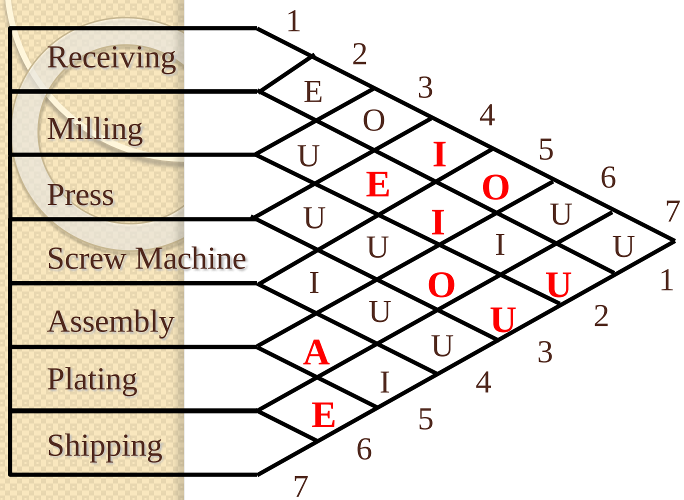
f_{ij}= Relationship value between department ***i*** to department ***j***

- Aldep uses (f_i values) **A**=64, **E**=16, **I**=4, **O**=1, **U**=0, and **X**=-1024
- The ranking of layouts is sensitive to the weight values. Layout "B" may be preferred to "C" with certain weights but not with others.
- The weights f_i can also be represented by the flow amounts between the adjacent departments instead of scores assigned to A, E, I, O, U, X.

Adjacency Based Scoring

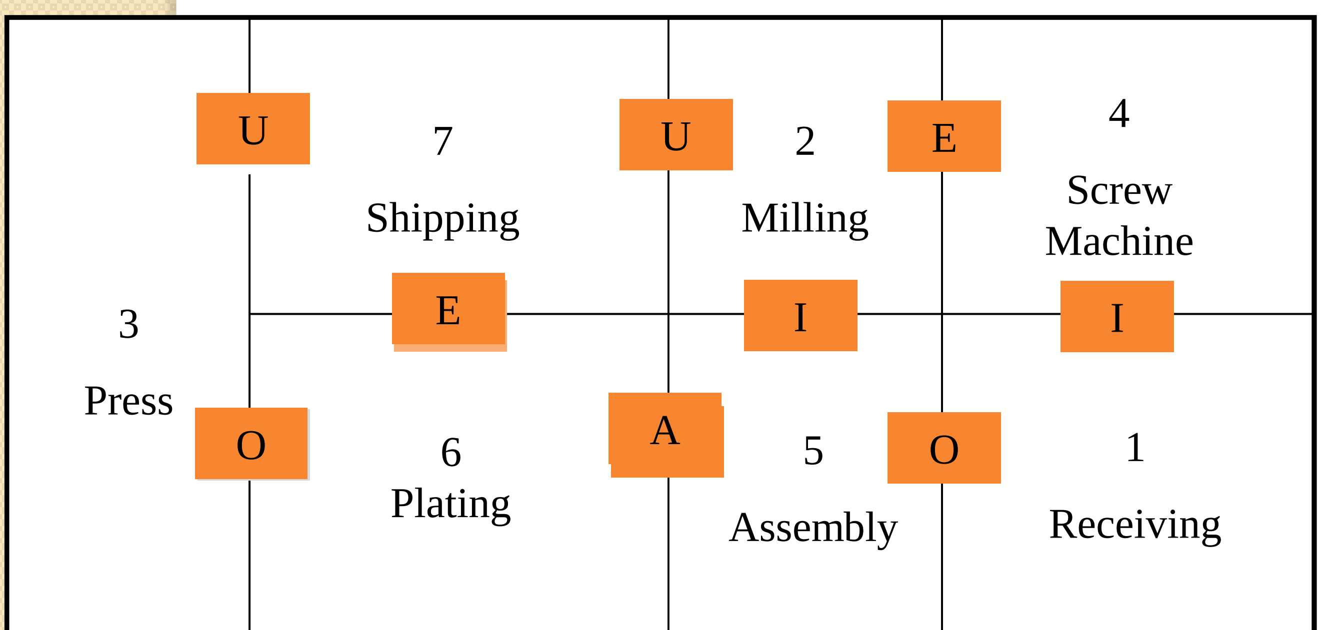
Example

$$z = f_{ij} x_{ij}$$



	1	2	3	4	5	6	7		
1				I	O			4+1	=5
2				E	I		U	16+4+0	=20
3						O	U	1+0	=1
4								----	
5						A		64	=64
6							E	16	=16
7									

Total Score 106



Weights:

A=64

E=16

I=4

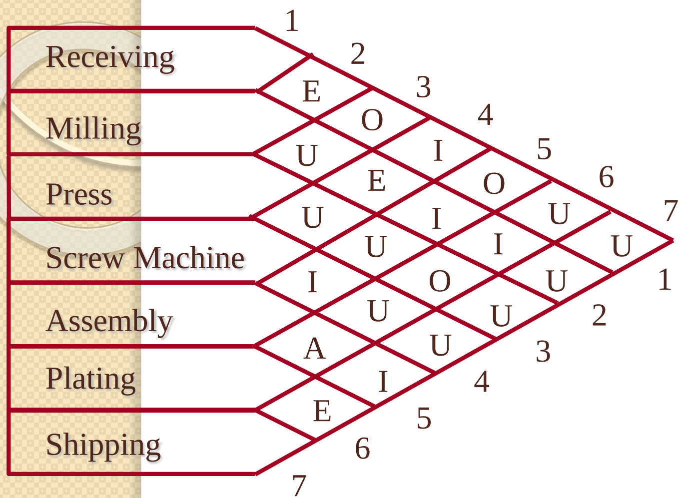
O=1

U=0

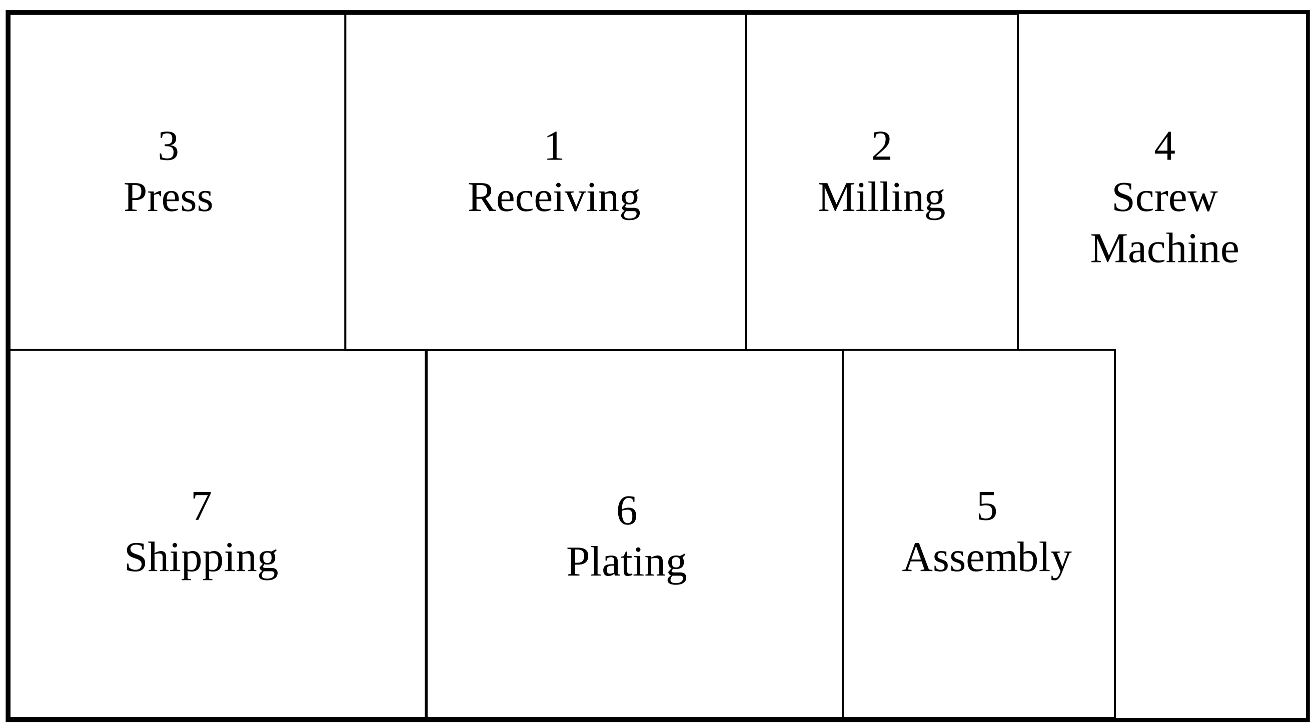
X=-1024

Adjacency Based Scoring

Example



Exercise: **Find the score of the layout shown below. Use A=8, E=4, I=2, O=1, U=0 and X=-8.**



Layout Evaluation
Adjacency Based Scoring

- **Efficiency rating:** When we compare the alternatives, we normalize each objective function

$$z = \frac{\sum_{i=1}^{m-1} \sum_{j=i+1}^{m} f_{ij} x_{ij}}{\sum_{i=1}^{m-1} \sum_{j=i+1}^{m} f_{ij}}$$

Layout Evaluation

Distance Based Scoring

- Suitable for input data from From-to chart
- Approximates the cost of flow between activities
- Requires explicit evaluation of the flow volumes and costs

$$\min z = \sum_{i=1}^{m} \sum_{j=1}^{m} f_{ij} c_{ij} d_{ij}$$

m: number of departments
f_{ij}: flow from department ***i*** to department ***j***
c_{ij}: cost of moving from ***i*** to ***j***
d_{ij}: the distance between departments ***i*** and ***j***

- Distance often depends on the aisle layout and material handling equipment
- Distance is often calculated as the rectilinear distance between department centroids

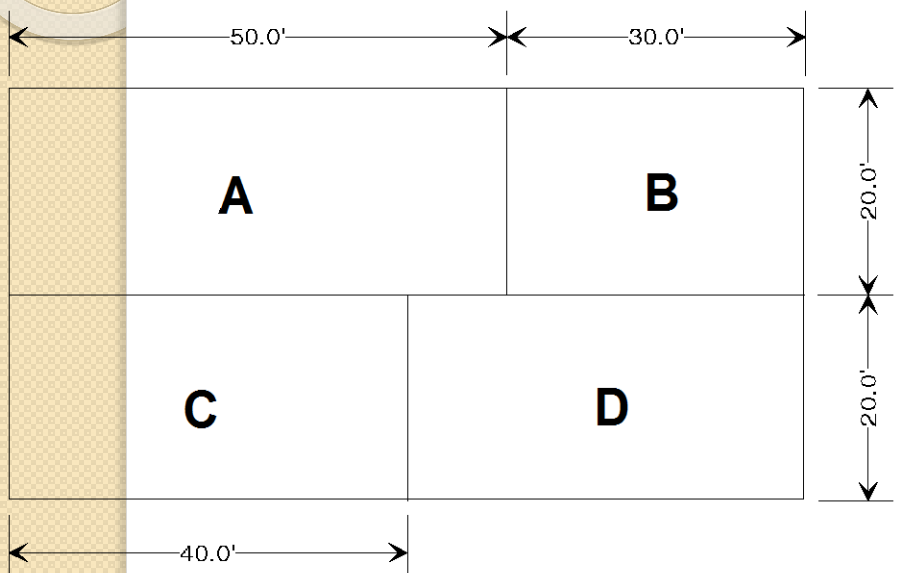
Layout Evaluation

Distance Based Scoring

$$z = f_{ij} c_{ij} d_{ij}$$

Example

Initial Layout



Flow Data f_{ij}

From/To	A	B	C	D
A	-	2	4	4
B	1	-	1	3
C	2	1	-	2
D	4	1	0	-

Distance Data d_{ij}

From/To	A	B	C	D
A	-	40	25	55
B	40	-	65	25
C	25	65	-	40
D	55	25	40	-

Total Score (Cost) Z

From/To	A	B	C	D	Total
A	-	80	100	220	400
B	40	-	65	75	180
C	50	65	-	80	195
D	220	25	0	-	245
Total	310	170	165	375	1020

Layout construction

- Development of the block layout from scratch
- We need to have
  - Relationship diagram
  - Space requirements

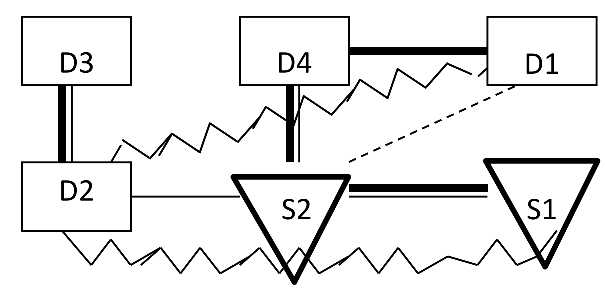
Relationship Diagram

- Transformation of Relationship Chart to a spatial organization of departments

Relationship Chart

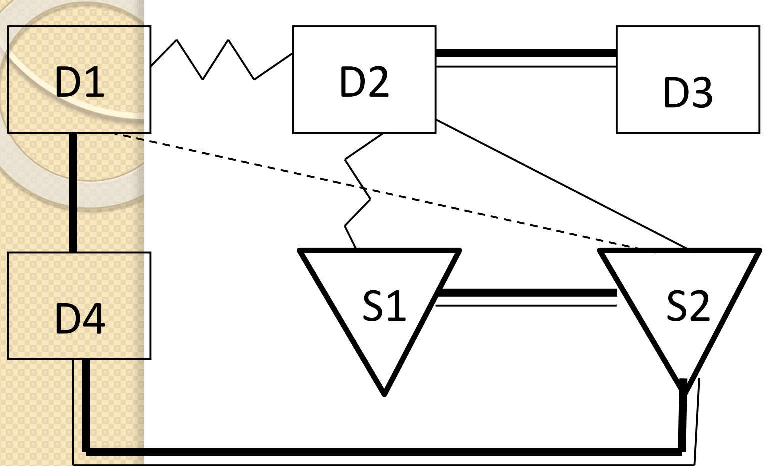
	D1	D2	D3	D4	S1	S2
Dept.1		XX	U	E	U	O
Dept.2			A	U	XX	I
Dept.3				U	U	U
Dept.4					U	A
Storage 1						A
Storage 2						

Relationship Diagram

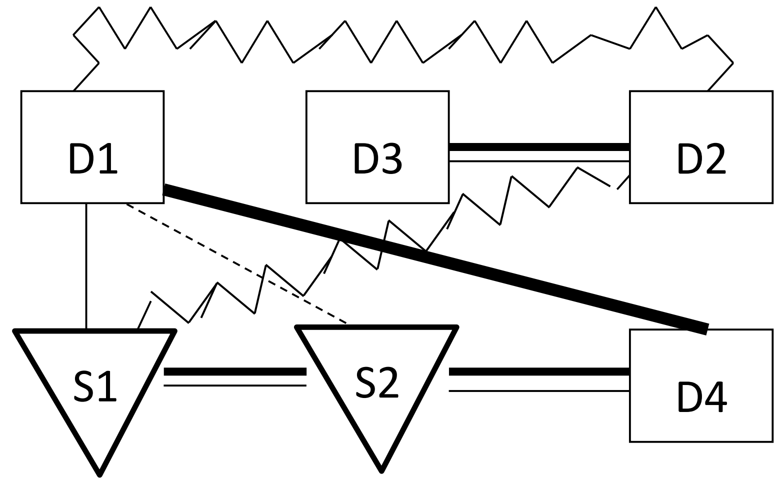


Value	Closeness Priority	Line Code
A	Absolutely important	
E	Specially important	
I	Important	
O	Importance	
U	Indiference	
X	Undesireble	

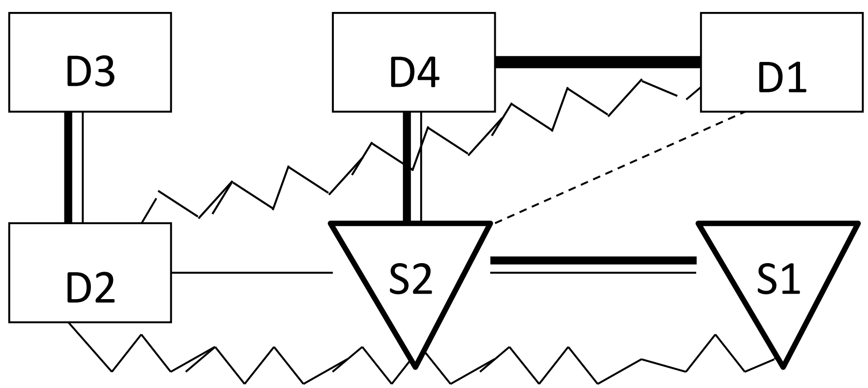
Relationship Diagram



Initial Diagram



First iteration



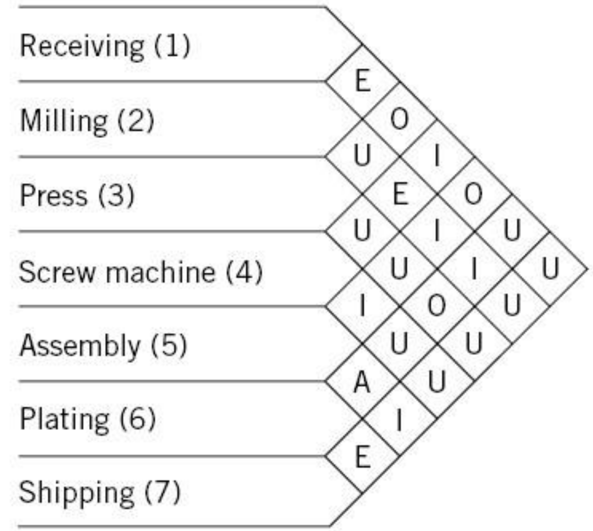
Second iteration (might be the optimum)

Relationship Diagram

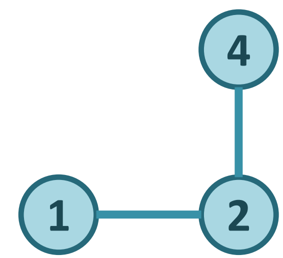
Method I.

- Place the departments among which there is “**A**” relationship
- Add the departments among which there is “**E**” relationship. Rearrange.
- Add the departments among which there is “**X**” relationship. Rearrange.
- Add the departments among which there is “**I**” relationship. Rearrange.
- Add the departments among which there is “**O**” relationship. Rearrange.
- Add the rest of the departments. Rearrange.
- Verify if all the departments are placed and if the important relations are respected

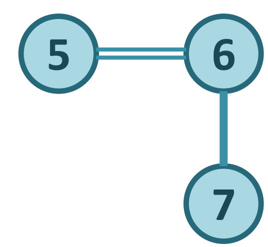
Relationship Diagram
Method I. - Example



- Place the departments among which there is “**A**” relationship



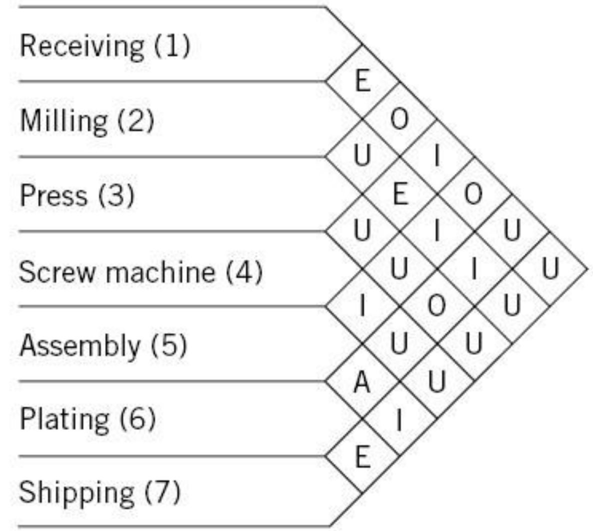
- Add the departments among which there is “**E**” relationship. Rearrange.

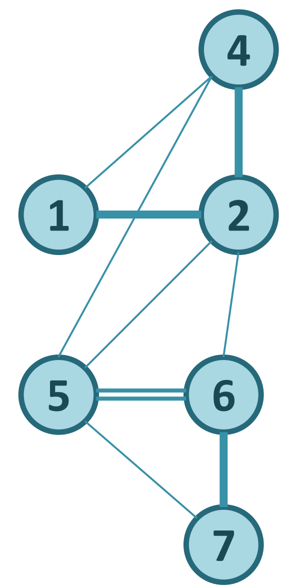


Relationship Diagram

Method I. - Example

- Add the departments among which there is "**X**" relationship. Rearrange.
- Add the departments among which there is "**I**" relationship. Rearrange.



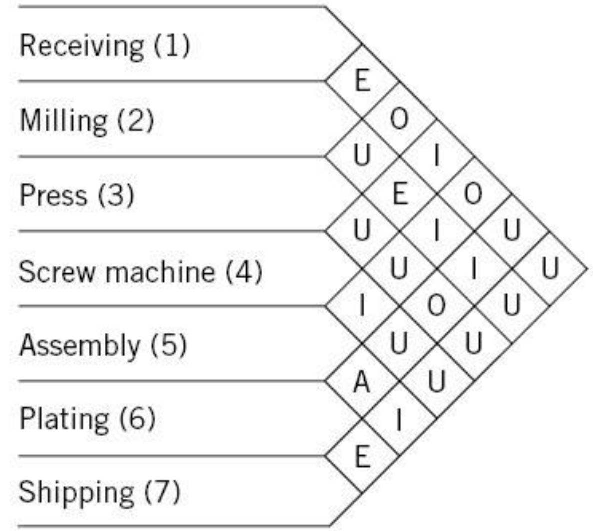


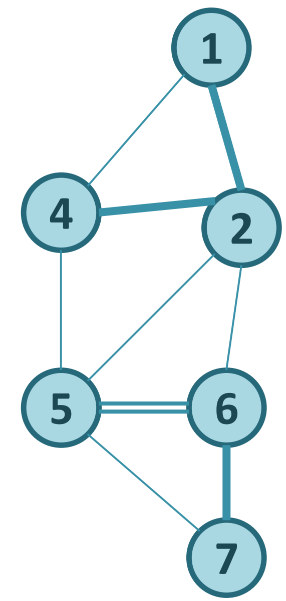
Relationship Diagram

Method I. - Example

- Add the departments among which there is "**X**" relationship. Rearrange.

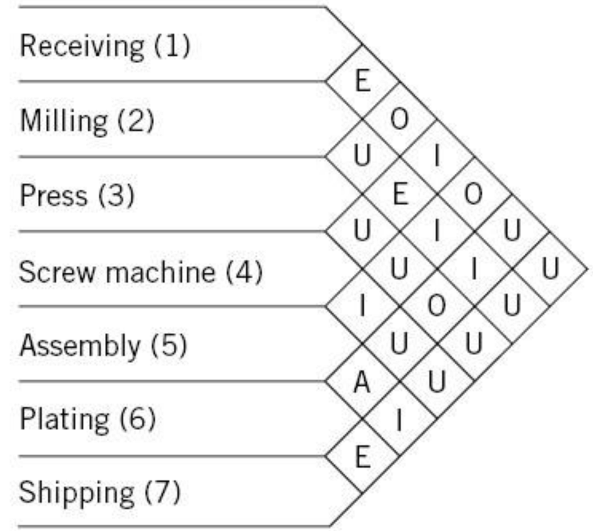
- Add the departments among which there is "**I**" relationship. Rearrange.

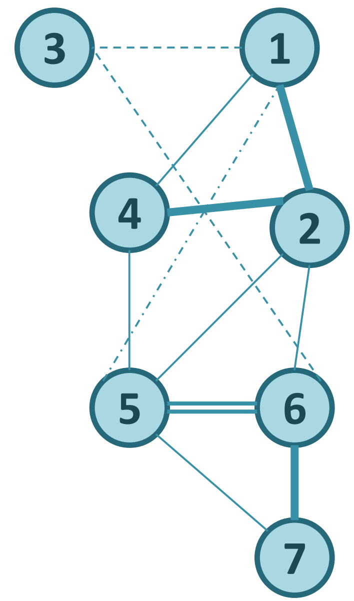




Relationship Diagram
Method I. - Example

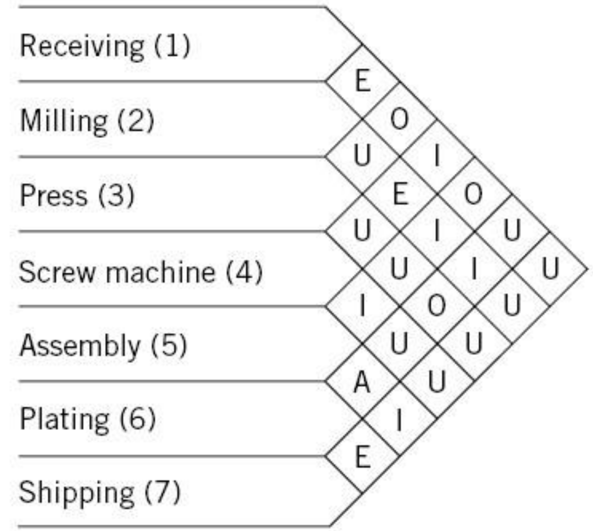
- Add the departments among which there is "**O**" relationship. Rearrange.
- Add the rest of the departments. Rearrange.
- Verify if all the departments are placed and if the important relations are respected

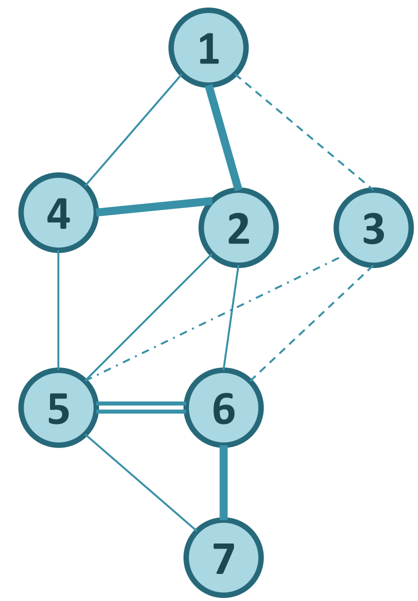




Relationship Diagram
Method I. - Example

- Add the departments among which there is "**O**" relationship. Rearrange.
- Add the rest of the departments. Rearrange.
- Verify if all the departments are placed and if the important relations are respected





Placing sequence: 5,6 – 1,2,4,7 - 3

Relationship Diagram

Method II. - Example

- Procedure:

Step 1. Select the first department to enter the layout
- select the department with the greatest # of "A"

Step 2. Select the second department to enter the layout – have an "A" with the 1st department

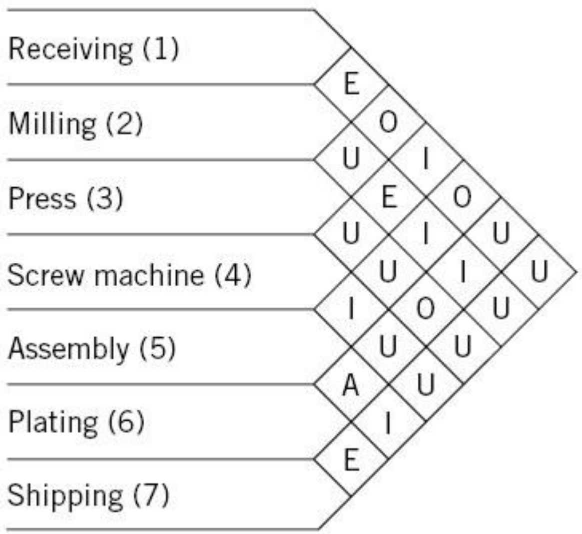
Step 3. Select the third department to enter the layout
- AA, AE, AI, A*, EE, EI, E*, II, I*

Step 4. Determine the fourth department to enter the layout - AAA, AAE, AAI, AA*, AEE, AEI

Step *n*. Department n is placed according to the rules described in Steps 3 and 4

* is for "O" or "U"

Relationship Diagram
Method II. - Example

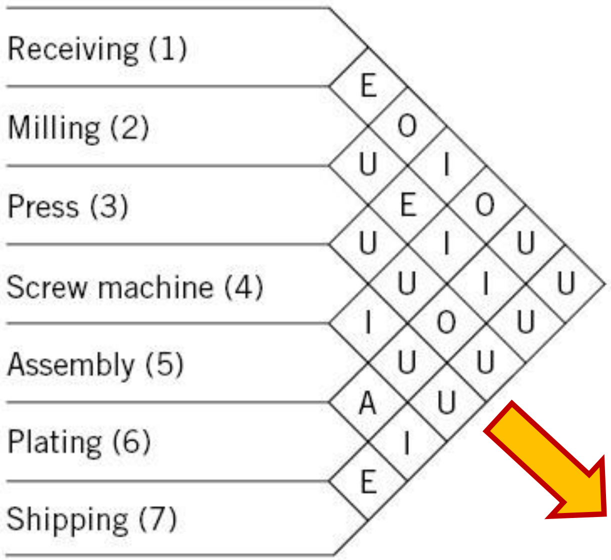


Depart.	Function	Area (ft^2)
D1	Receiving	12,000
D2	Milling	8,000
D3	Press	6,000
D4	Screw machine	12,000
D5	Assembly	8,000
D6	Plating	12,000
D7	Shipping	12,000

- Determine a layout with actual dimensions of the departments

Relationship Diagram

Method II. - Example



- Transform Activity relationship chart to **relationship diagram worksheet**

Rel	D1	D2	D3	D4	D5	D6	D7
A					6	5	
E	2	1 - 4		2		7	6
I	4	5 - 6		1 - 5	2 – 4 - 7	2	5
O	3 - 5		1 - 6		1	3	
U	6 - 7	3 - 7	2 – 4 - 5 - 7	3 – 6 - 7	3	1 - 4	1 – 2 - 3 - 4
X							

Relationship Diagram

Method II. - Example

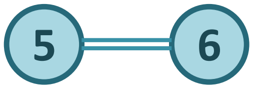
- ***Step 1)*** Select the department with the greatest # of A
  - If a tie exists, select the one with greatest # of E, greatest # of I, greatest # of X
  - **6 or 5 => 6 is selected** (has more E relationships)

6

Rel	D1	D2	D3	D4	D5	D6	D7
A					6	5	
E	2	1 - 4		2		7	6
I	4	5 - 6		1 - 5	2 – 4 - 7	2	5
O	3 - 5		1 - 6		1	3	
U	6 - 7	3 - 7	2 – 4 - 5 – 7	3 – 6 - 7	3	1 - 4	1 – 2 - 3 - 4
X							

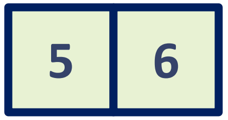
6

Relationship Diagram
Method II. - Example



- ***Step 2)*** Select the department which has the greatest # of A with the first department
  - **5 is selected *(A with 6)***

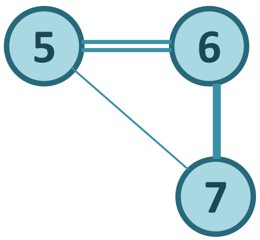
Rel	D1	D2	D3	D4	D5	D6	D7
A					6	5	
E	2	1 - 4		2		7	6
I	4	5 - 6		1 - 5	2 – 4 - 7	2	5
O	3 - 5		1 - 6		1	3	
U	6 - 7	3 - 7	2 – 4 - 5 - 7	3 – 6 - 7	3	1 - 4	1 – 2 - 3 - 4
X							



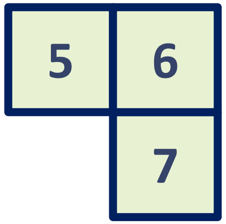
Relationship Diagram

Method II. - Example

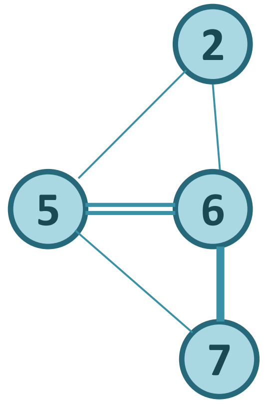
- ***Step 3)*** Select the next department with the highest combined relationship with the departments already in the layout: AA, AE, AI, A*, EE, EI, E*, II, I*
  - **7 is selected *(EI)***



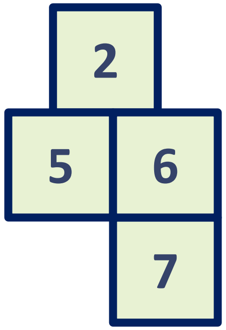
Rel	D1	D2	D3	D4	D5	D6	D7
A					6	5	
E	2	1 - 4		2		7	6
I	4	5 - 6		1 - 5	2 – 4 - 7	2	5
O	3 - 5		1 - 6		1	3	
U	6 - 7	3 - 7	2 – 4 - 5 - 7	3 – 6 - 7	3	1 - 4	1 – 2 - 3 - 4
X							



Relationship Diagram
Method II. - Example



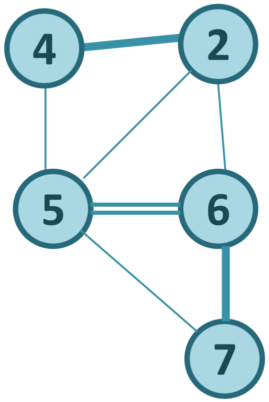
- ***Step 4)*** Select the next department with the highest combined relationship with the departments already in the layout: AAA, AAE, AAI, AA*, AEE, AEI, AE*, AII, AI*. A**, EEE, EEI, EE*, EII, EI*, E**, III, II*, I**
  - **2 is selected *(II*)*** *(4 has I**)*



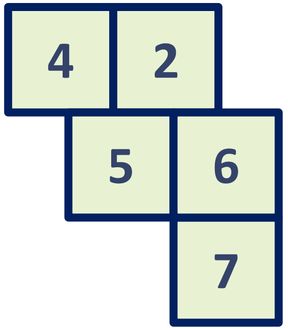
Rel	D1	D2	D3	D4	D5	D6	D7
A					6	5	
E	2	1 - 4		2		7	6
I	4	5 - 6		1 - 5	2 – 4 - 7	2	5
O	3 - 5		1 - 6		1	3	
U	6 - 7	3 - 7	2 – 4 - 5 - 7	3 – 6 - 7	3	1 - 4	1 – 2 - 3 - 4
X							

Relationship Diagram

Method II. - Example



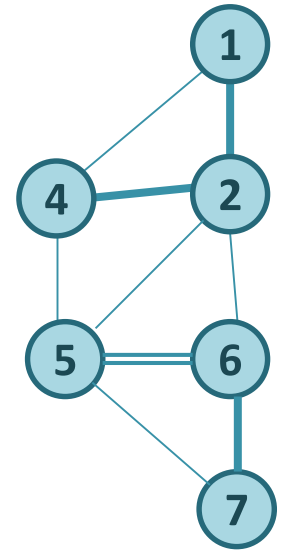
- ***Step n)*** Each following department is placed based on the rules described in Steps 3 and 4.
  - **4 is selected *(EI**)*** *(1 has E***)*



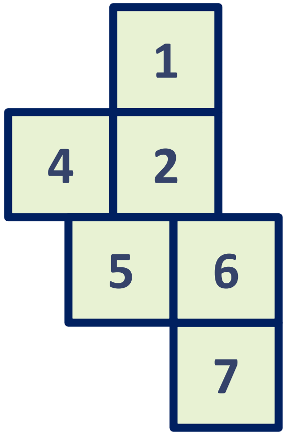
Rel	D1	D2	D3	D4	D5	D6	D7
A					6	5	
E	2	1 - 4		2		7	6
I	4	5 - 6		1 - 5	2 – 4 - 7	2	5
O	3 - 5		1 - 6		1	3	
U	6 - 7	3 - 7	2 – 4 - 5 - 7	3 – 6 - 7	3	1 - 4	1 – 2 - 3 - 4
X							

Relationship Diagram

Method II. - Example



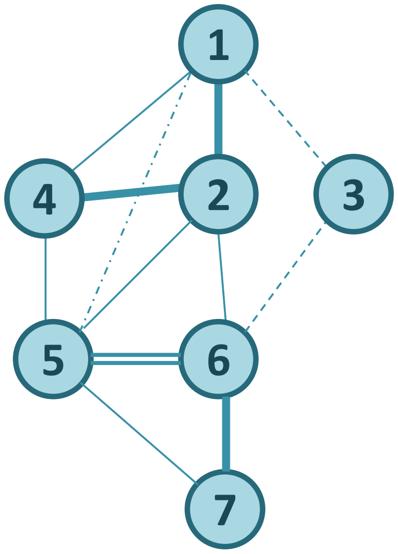
- ***Step n)*** Each following department is placed based on the rules described in Steps 3 and 4.
  - **1 is selected *(EI***)***



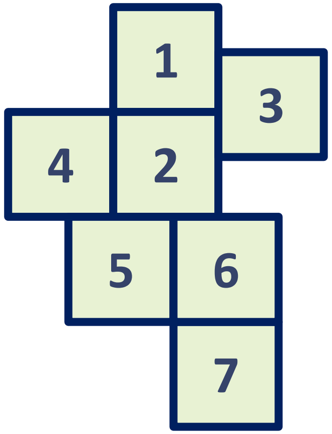
Rel	D1	D2	D3	D4	D5	D6	D7
A					6	5	
E	2	1 - 4		2		7	6
I	4	5 - 6		1 - 5	2 – 4 - 7	2	5
O	3 - 5		1 - 6		1	3	
U	6 - 7	3 - 7	2 – 4 - 5 - 7	3 – 6 - 7	3	1 - 4	1 – 2 - 3 - 4
X							

Relationship Diagram

Method II. - Example



- ***Step n)*** Each following department is placed based on the rules described in Steps 3 and 4.
  - **3 is selected *(******)***



Rel	D1	D2	D3	D4	D5	D6	D7
A					6	5	
E	2	1 - 4		2		7	6
I	4	5 - 6		1 - 5	2 – 4 - 7	2	5
O	3 - 5		1 - 6		1	3	
U	6 - 7	3 - 7	2 – 4 - 5 - 7	3 – 6 - 7	3	1 - 4	1 – 2 - 3 - 4
X							

Placing sequence: 6-5-7-2-4-1-3

Relationship Diagram
Method II. - Example

- Determine # of unit area templates

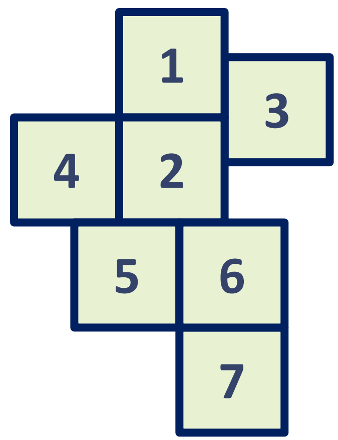
Depart.	Function	Area (ft^2)	# of unit area templates
D1	Receiving	12,000	6
D2	Milling	8,000	4
D3	Press	6,000	3
D4	Screw machine	12,000	6
D5	Assembly	8,000	4
D6	Plating	12,000	6
D7	Shipping	12,000	6

Relationship Diagram

Method II. - Example

- Apply the actual dimensions to the block layout

Depart.	# of unit area templates
D1	6
D2	4
D3	3
D4	6
D5	4
D6	6
D7	6



Block layout

	1	1	1
4	4	1	1
4	4	3	1
4	2	3	3
4	2	2	2
5	6	6	6
5	6	6	6
5	7	7	7
5	7	7	7

Final layout

- Several block template layouts and final layouts should be developed

Next lecture

- Layout construction methods