Flow, Space and Activity Relationships II.

- Chapter 3 of the textbook
- Activity relationships
- Flow
- Space

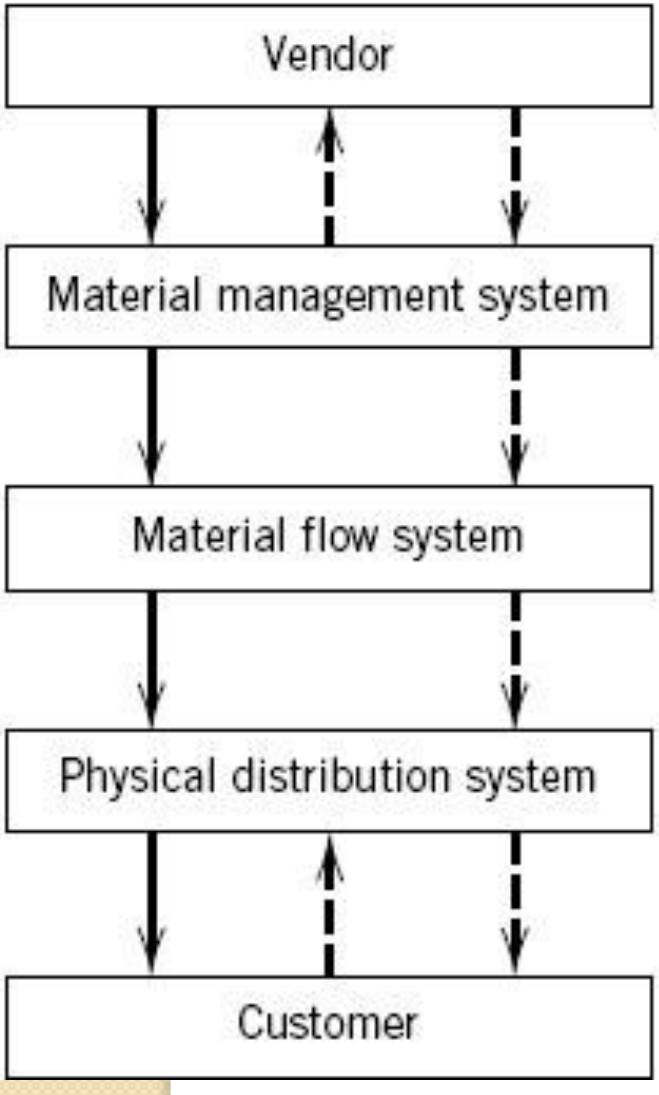
Flow, Space and Activity Relationships II.

- Activity relationships
  - Activity relationships are the key input in facilities design
- Flow
  - Flow of materials, people, equipment, information, money, etc.
  - Flow patterns, flow measuring and graphical analysis of the flows
- Space
  - The amount of space required in the facility
  - Workstation specification, department specification and other space requirements

Activity Relationships

- Activity relationships are the key input in facilities design
- Defined by:
  - Flow relationships
  - Organizational relationships
  - Environmental relationships
  - Control relationships
  - Process relationships

Logistics system



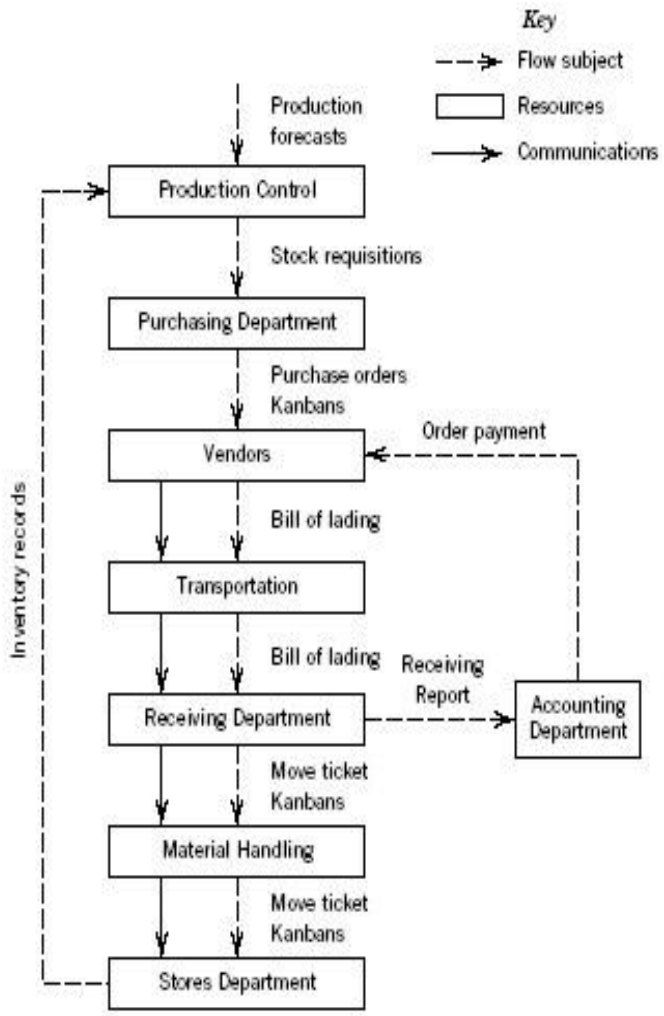
← Flow ***into*** a manufacturing facility

← Flow ***within*** a manufacturing facility

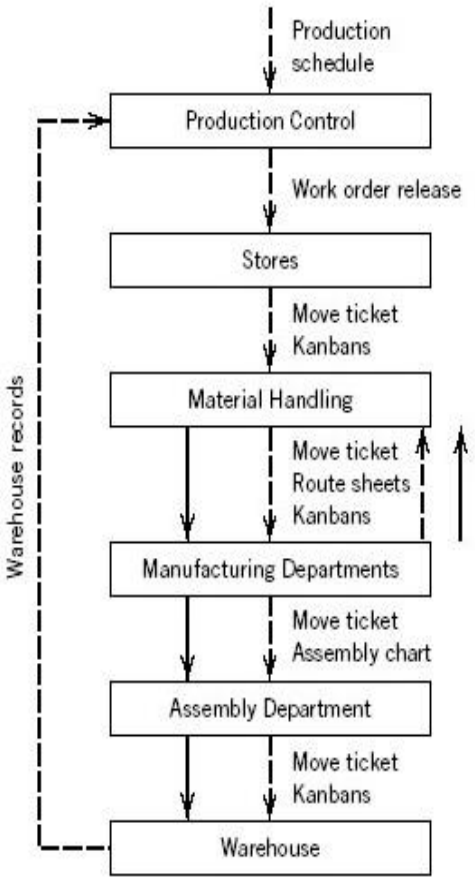
← Flow ***from*** a manufacturing facility

Segments of flow

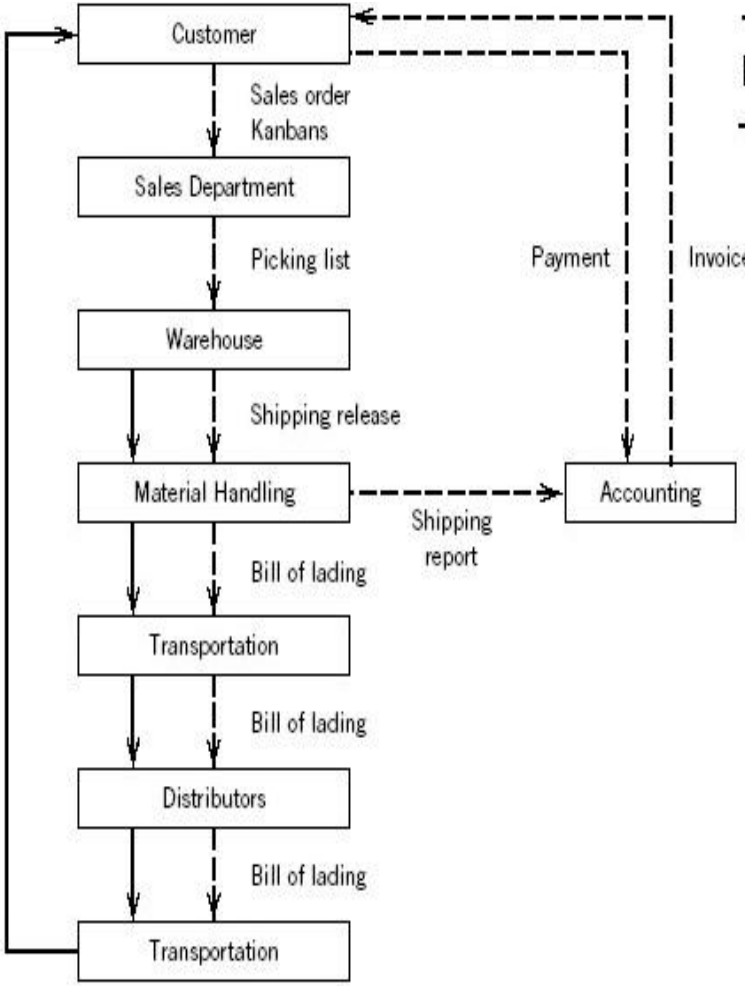
Flow of materials **INTO** facility



Flow of materials **WITHIN** facility



Flow of products **FROM** facility



Flow Patterns

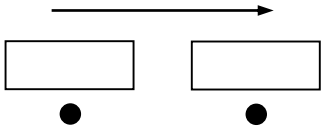
Within the overall flow environment, a critical consideration is the pattern of flow.

- ***Flow within workstations***
  - Motion studies and ergonomics considerations
  - Flow should be simultaneous, coordinated, symmetrical, natural, rhythmical, and habitual
- ***Flow within departments***
  - Is dependent on the type of department (product vs. process dept.)
- ***Flow between departments***
  - Used to evaluate overall flow within facility

Flow Patterns: Flow within Departments

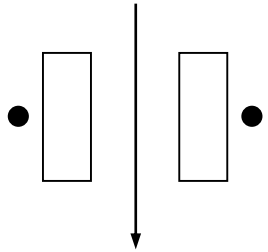
- ***Product departments flow:*** in a product and/or product family department

1 machine/operator



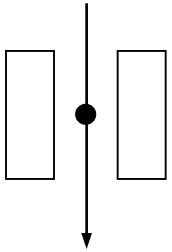
END-TO-END

1 machine/operator



BACK-TO-BACK

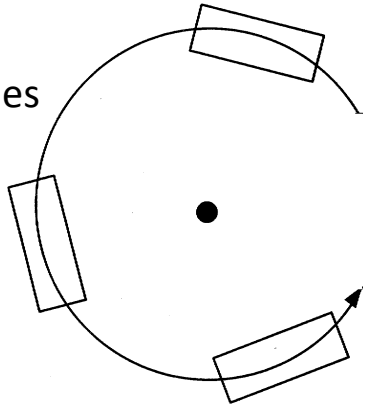
2 machines/operator



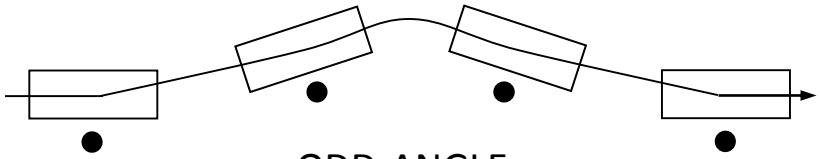
FRONT-TO-FRONT

More than 2 machines /operator

CIRCULAR



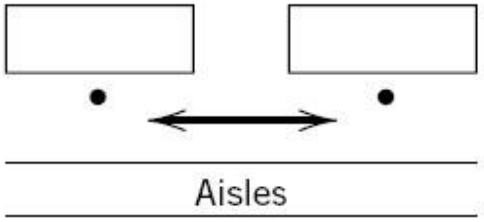
1 machine/operator



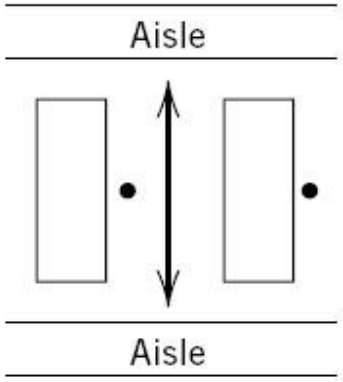
ODD-ANGLE

Flow Patterns: Flow within Departments

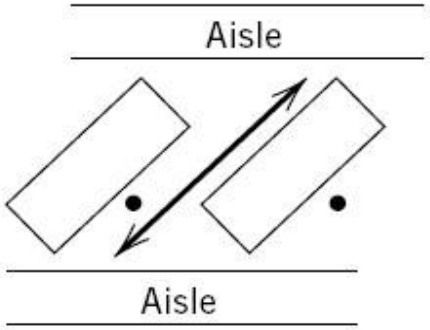
- ***Process departments flow:*** in a process department
  - Little flow between workstations
  - Flow occurs between workstations and aisles



PARALLEL FLOW



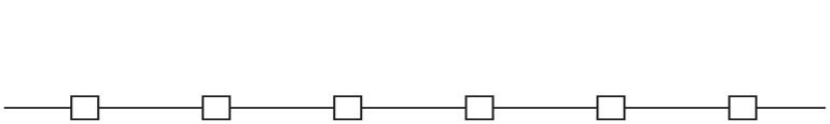
PERPENDICULAR FLOW



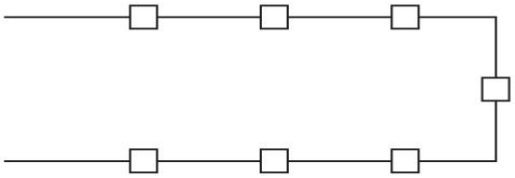
DIAGONAL FLOW

Flow Patterns: Flow within Departments

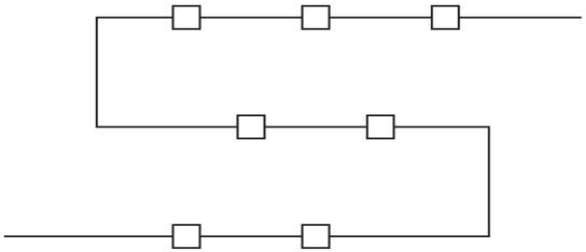
- Flow within departments with material handling considerations → Line flow patterns



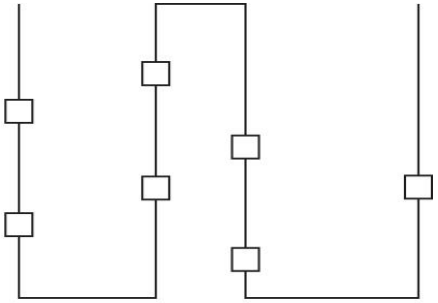
Straight: I-flow



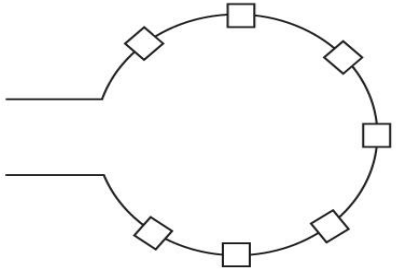
U - flow



S - flow



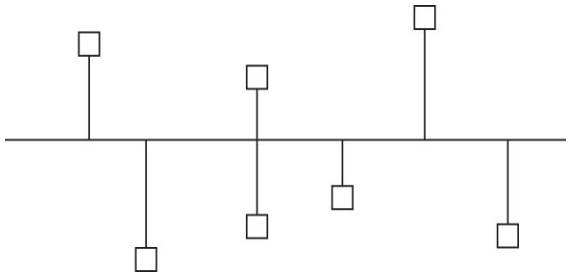
W - flow



O - flow

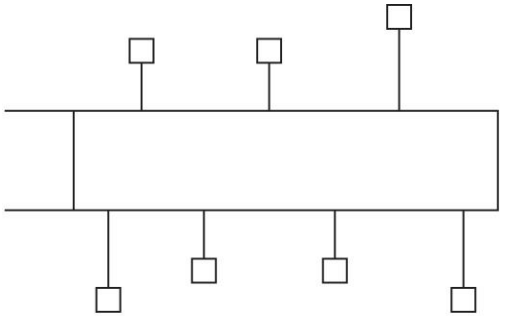
Flow Patterns: Flow within Departments

- Flow within departments with material handling considerations → Spine, tree and loop flow patterns

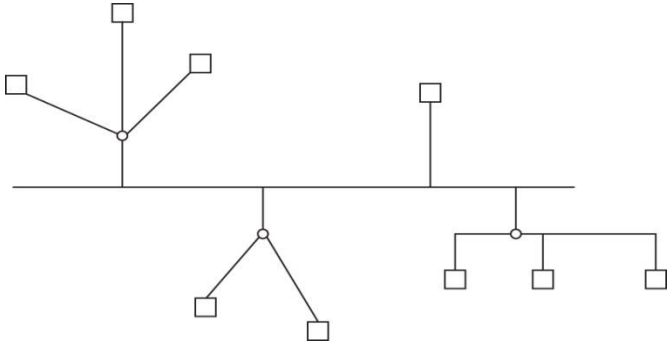


Spine flow pattern

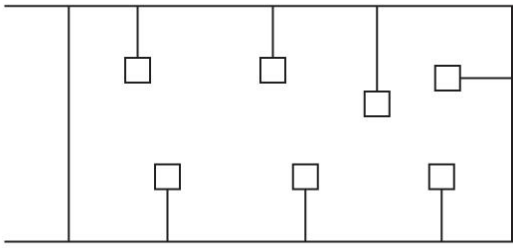
Loop flow patterns:



Inner loop



Tree flow pattern

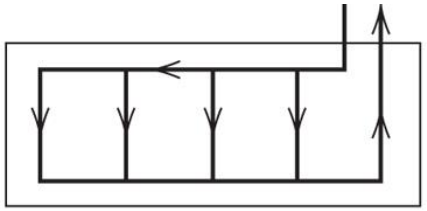


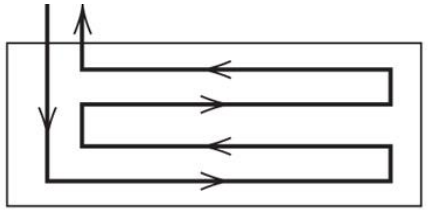
Outer loop

Flow Patterns: Flow between Departments

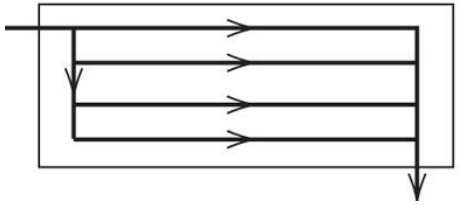
- Flow within a facility considering the locations of entrance and exit

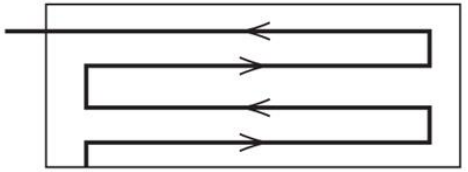
At the same location



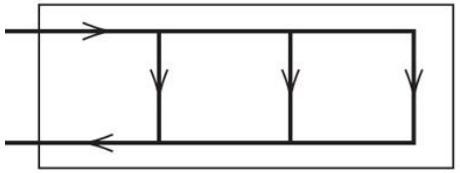


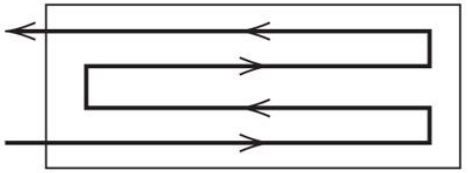
On adjacent sides



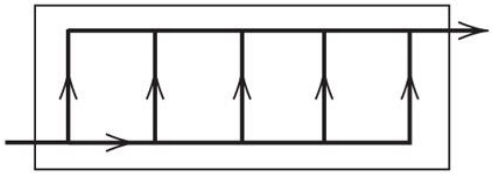


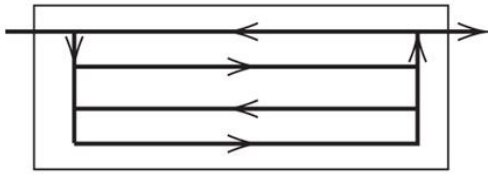
On the same side





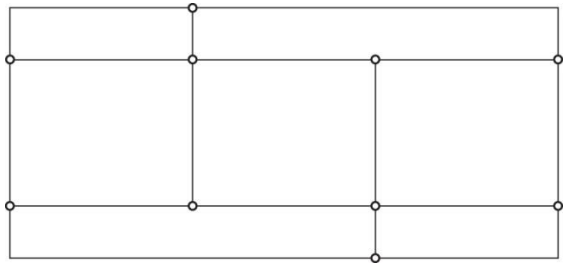
On opposite sides



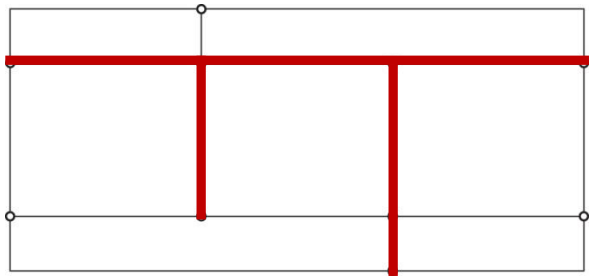


Flow Patterns: Flow between Departments

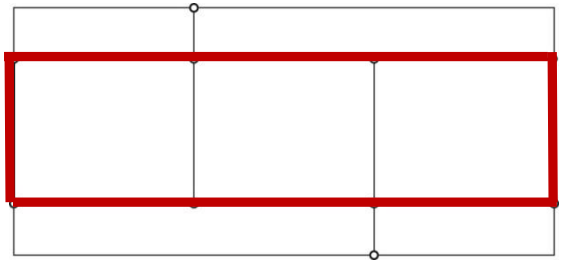
- Flow within a facility - pattern categories



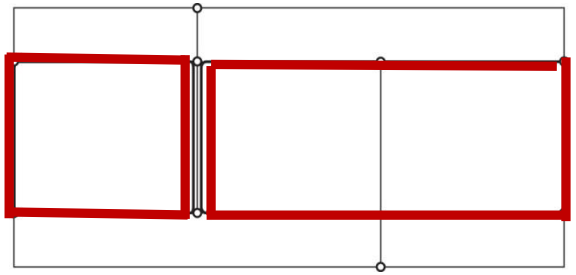
Conventional structure



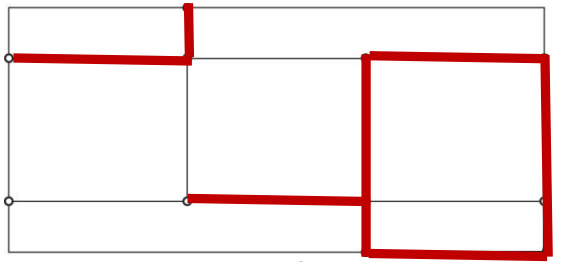
Spine structure



Loop structure



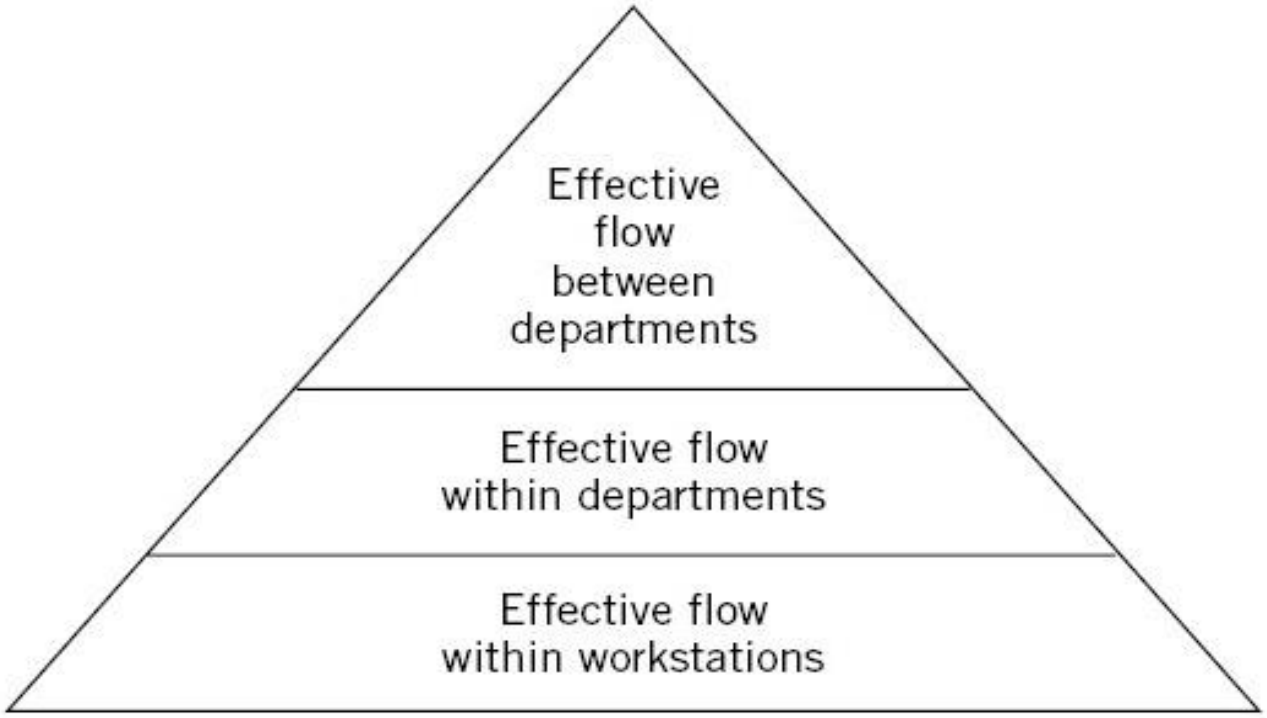
Tandem structure



Segmented structure

Flow Planning

- The effective flow within a facility depends on effective *flow between departments*. Such flow depends on effective *flow within departments*, which depends on effective *flow within workstations*.

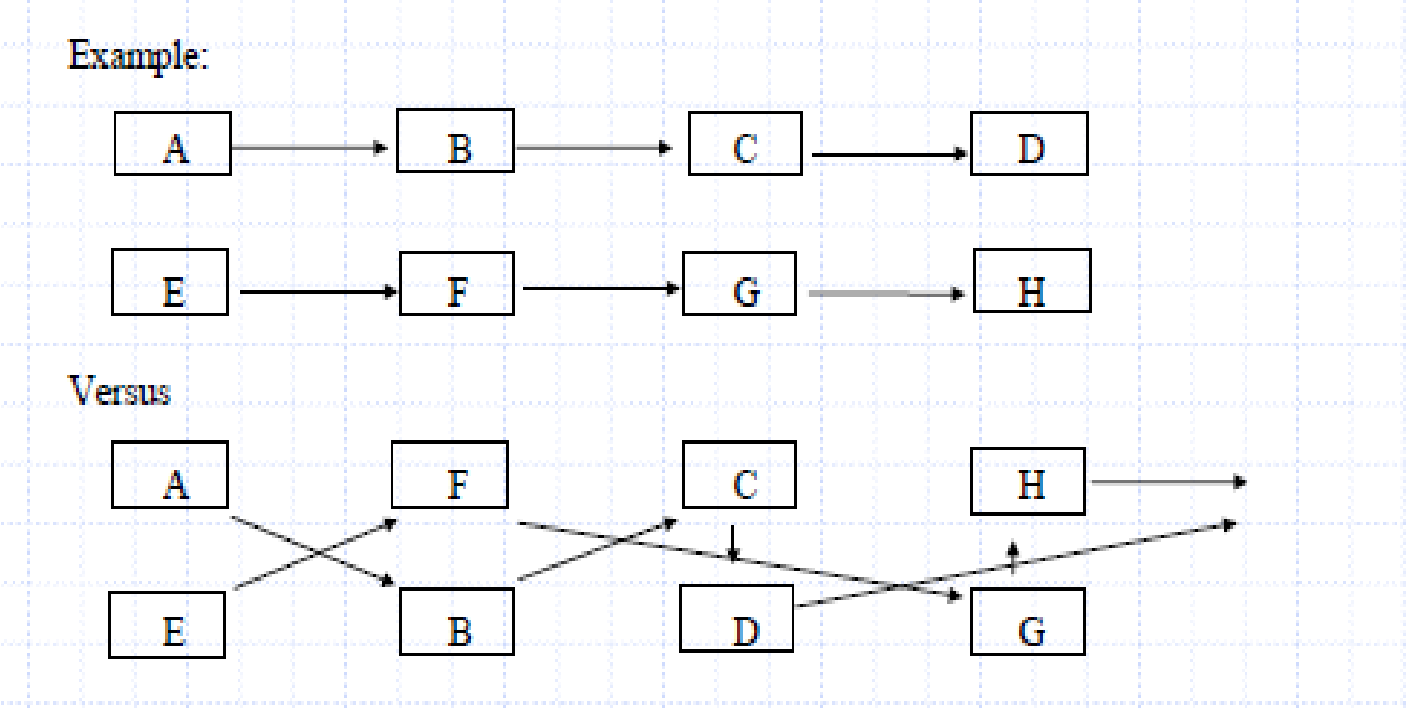


Signs of a good general flow pattern

- A flow starts at receiving and terminates at shipping.
- Straight and short lines of flow
- Minimum backtracking
- Material is moved directly to point of use
- Minimum WIP
- Flow pattern is easily expandable, new processes can easily be merged in

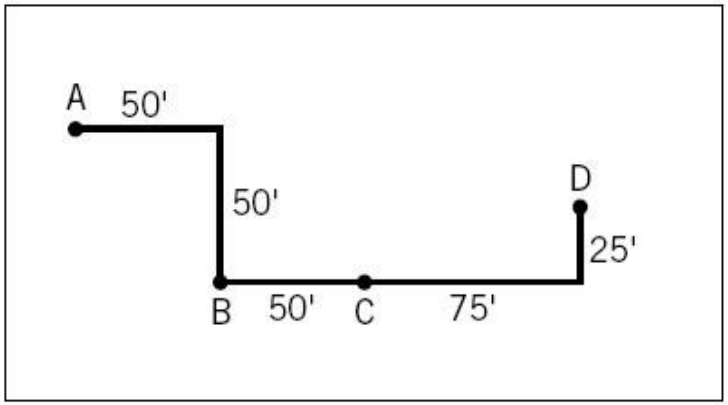
Principles of effective flow

- Maximize directed (uninterrupted) flow paths



Principles of effective flow

- Minimize backtracking: Backtracking increases the length of the flow path



Flow Path A – B – C – D

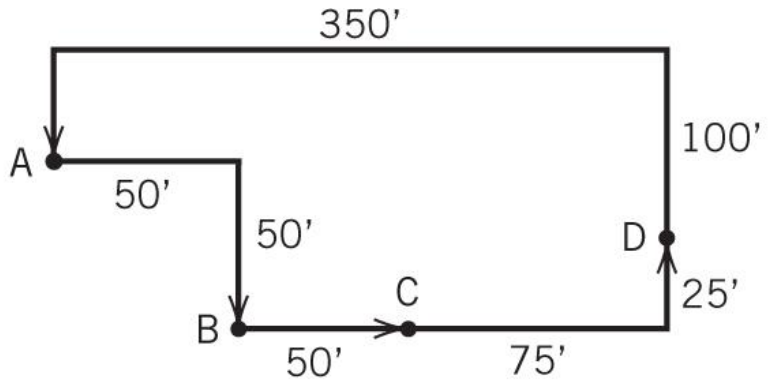
(50' + 50') + 50' + (75' + 25') = 250 feet

Flow Path A – B – A – C – D

(50' + 50') + (50' + 50') + (50' + 50') + 50') + (75' + 25') = 450 feet

Backtrack Penalty

Principles of effective flow



For path A – B – C – D

Total path = (50' + 50') + (50') + (75' + 25')

= 250 feet

For path A – B – A – C – D

Total path = (50' + 50') + [50' + (75' + 25') + 450'] + (50' + 50') + 50' + (75' + 25')

= 950 feet

Backtracking penalty

Effects of backtracking in a unidirectional loop flow system

Principles of effective flow

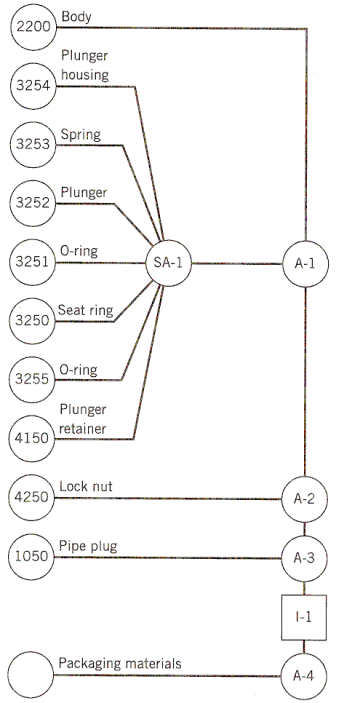
- Minimize flow
  - Deliver materials, information, or people directly to the point of ultimate use
  - Plan for flow between two consecutive points of use to take place in a few moments as possible
  - Combine flows and operations
- Maximize directed flow path
- Minimize the cost of the flow
  - Minimize manual handling (automate or mechanize the flow)
  - Minimize trips of empty carriers

Measuring Flow

- *Quantitative flow measurement*
  - Large volumes of materials, information, a number of people moving between departments
  - In terms of amount moved or distance travelled
- *Qualitative flow measurement*
  - Very little actual movement of materials, information, and people flowing between departments
  - Significant communication and organizational interrelation between departments
  - In terms of the level of relationship between units (departments) in the organizations
- Usually both measurements are used

Graphical tools for analysis and design of material flow system

- We already know:
  - Assembly chart

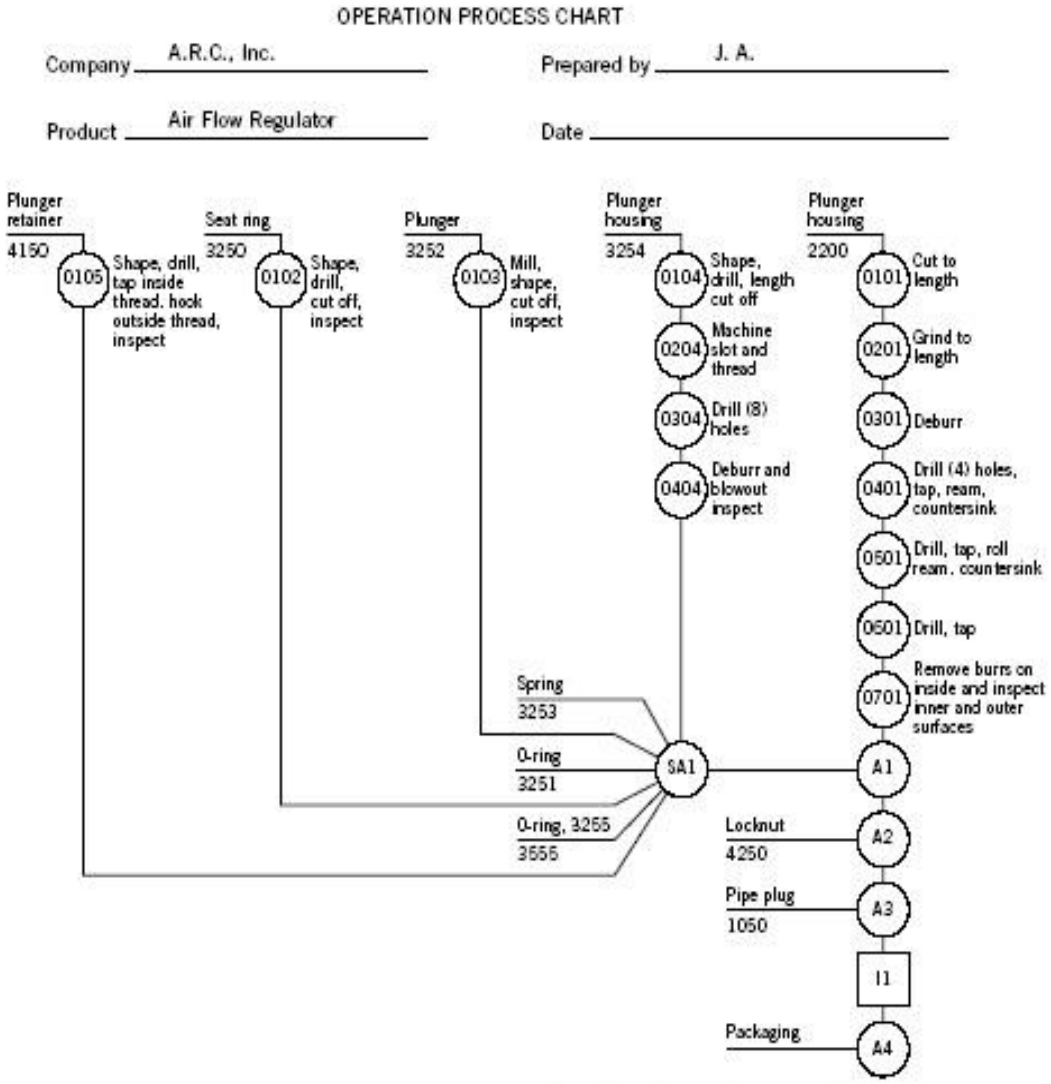


  - Operations process chart

- Facility planning specific tools:
  - Flow process chart
  - Flow diagram
  - From-to chart
  - Relationship chart
  - Relationship diagram

Flow process chart

- Flow Process Chart is similar to Operations Process Chart

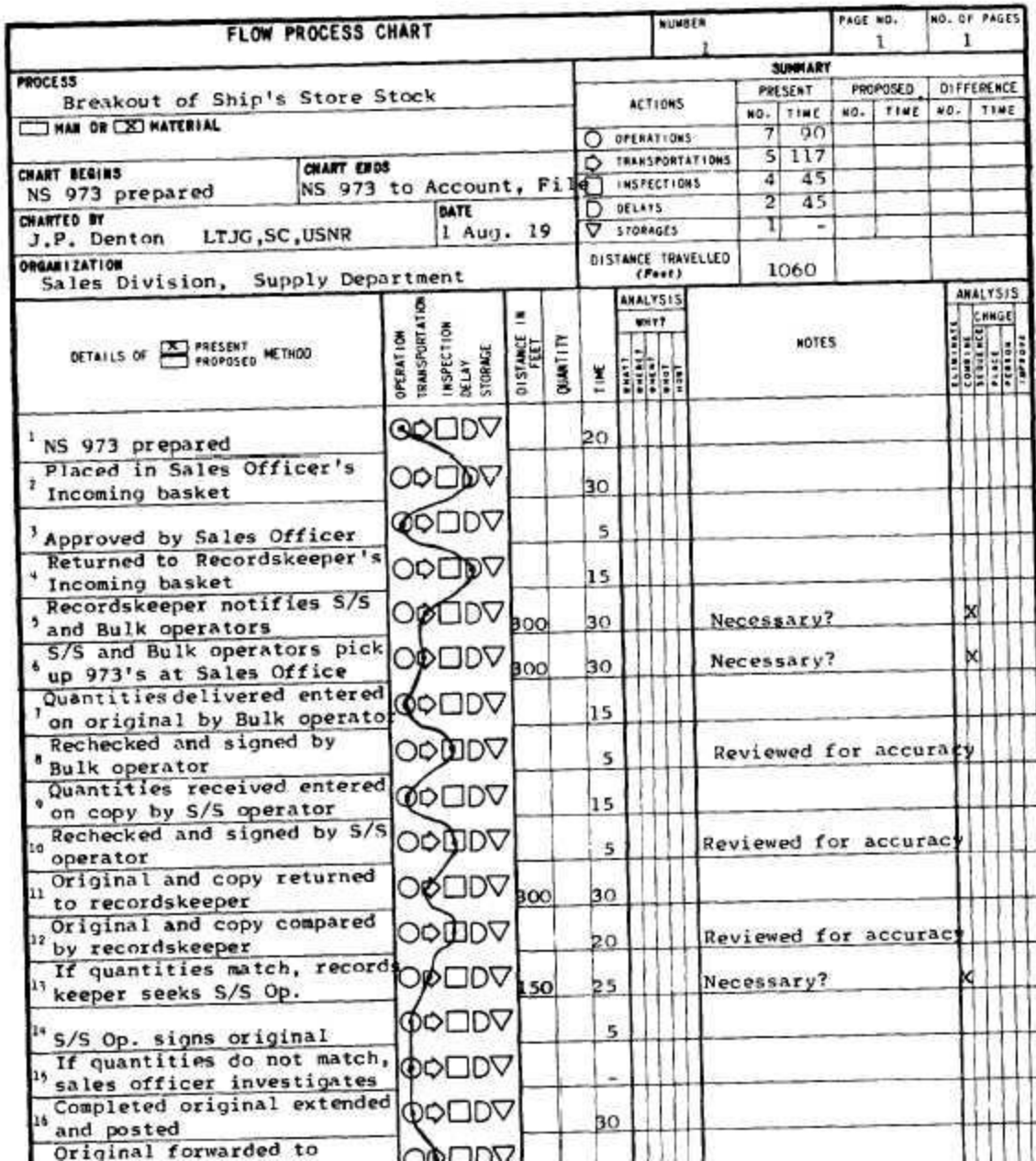


Flow process chart

- Flow Process Chart is similar to Operations Process Chart
- It shows assemblies, operations, and inspections, but also material handling and storage.

Symbol	Description
	Operation, work on the part
	Transportation, moving the part
	Delay, temporary storage, usually at a workstation.
	Inspection, quality control.
	Combination operation and inspection
	Permanent storage

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, Fil

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

DATE: 1 Aug. 19

ORGANIZATION: Sales Division, Supply Department

SUMMARY

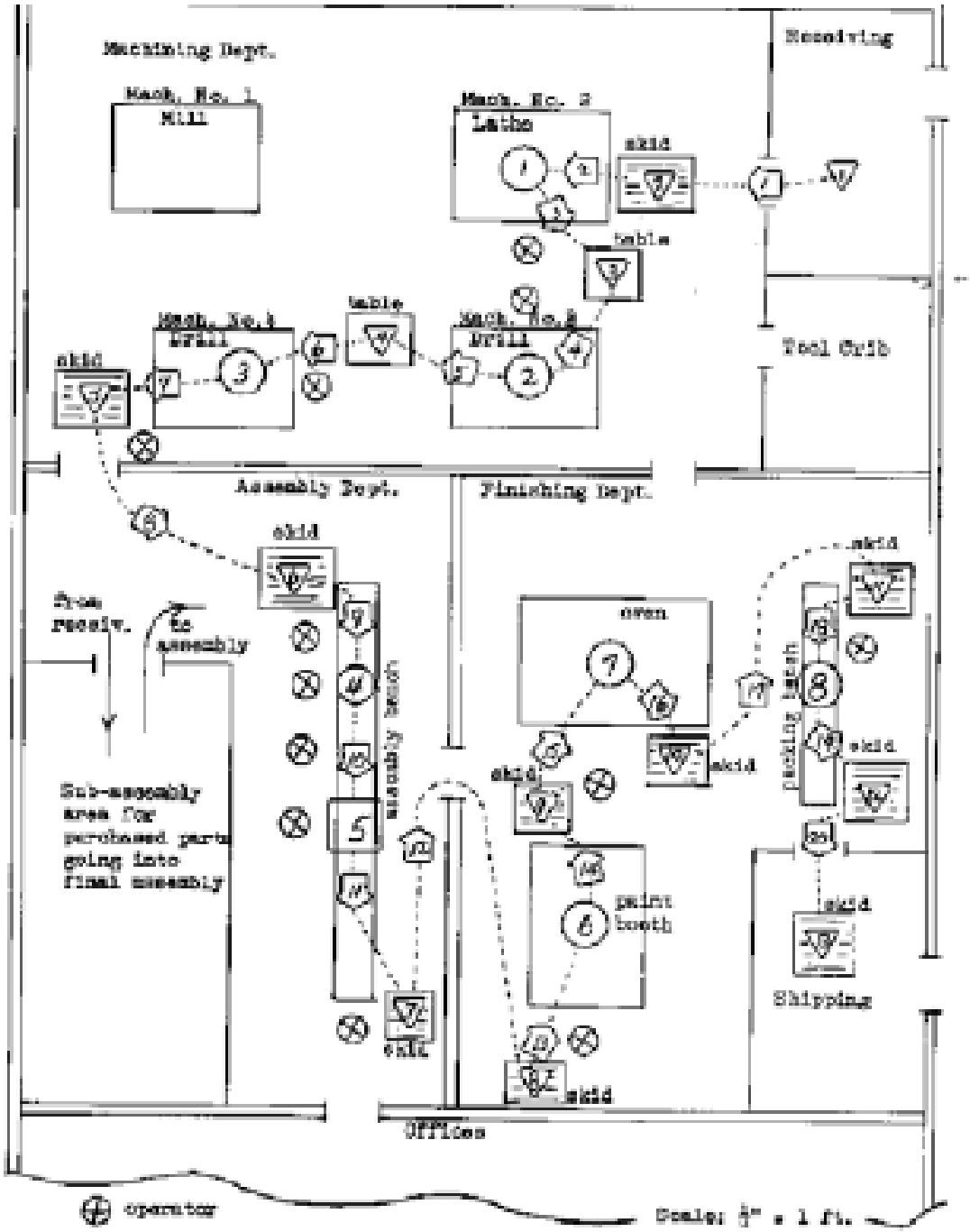
ACTIONS	PRESENT NO.	PRESENT TIME	PROPOSED NO.	PROPOSED TIME	DIFFERENCE NO.	DIFFERENCE TIME
OPERATIONS	7	90				
TRANSPORTATIONS	5	117				
INSPECTIONS	4	45				
DELAYS	2	45				
STORAGES	1	-				
DISTANCE TRAVELLED (Feet)		1060				

DETAILS OF ☒ PRESENT ☐ PROPOSED METHOD

	OPERATION	TRANSPORTATION	INSPECTION	DELAY	STORAGE	DISTANCE IN FEET	QUANTITY	TIME	ANALYSIS WHY?	NOTES	ANALYSIS CHANGE
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?	X
6 S/S and Bulk operators pick up 973's at Sales Office		●				300		30		Necessary?	X
7 Quantities delivered entered on original by Bulk operator	●							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			
12 Original and copy compared by recordskeeper			●					20		Reviewed for accuracy	
13 If quantities match, records keeper seeks S/S Op.	●					150		25		Necessary?	X
14 S/S Op. signs original	●							5			
15 If quantities do not match, sales officer investigates	●							-			
16 Completed original extended and posted	●							30			
Original forwarded to	●										

Flow diagram

- Flow Diagram is a flow process chart spread over the layout of the corresponding area.



From-To Chart

- From-To Chart measures the flows between departments
- It resembles mileage charts

From \ To	Atlanta, GA	Boston, MA	Chicago, IL	Dallas, TX	New York, NY	Pittsburgh, PA	Raleigh, NC	San Francisco, CA
Atlanta, GA		1037	674	795	841	687	372	2496
Boston, MA	1037		963	1748	206	561	685	3095
Chicago, IL	674	963		917	802	452	784	2142
Dallas, TX	795	1748	917		1552	1204	1166	1753
New York, NY	841	206	802	1552		368	489	2934
Pittsburgh, PA	687	561	452	1204	368		445	2578
Raleigh, NC	372	685	784	1166	489	445		2843
San Francisco, CA	2496	3095	2142	1753	2934	2578	2843	

Figure 3.29 Mileage chart.

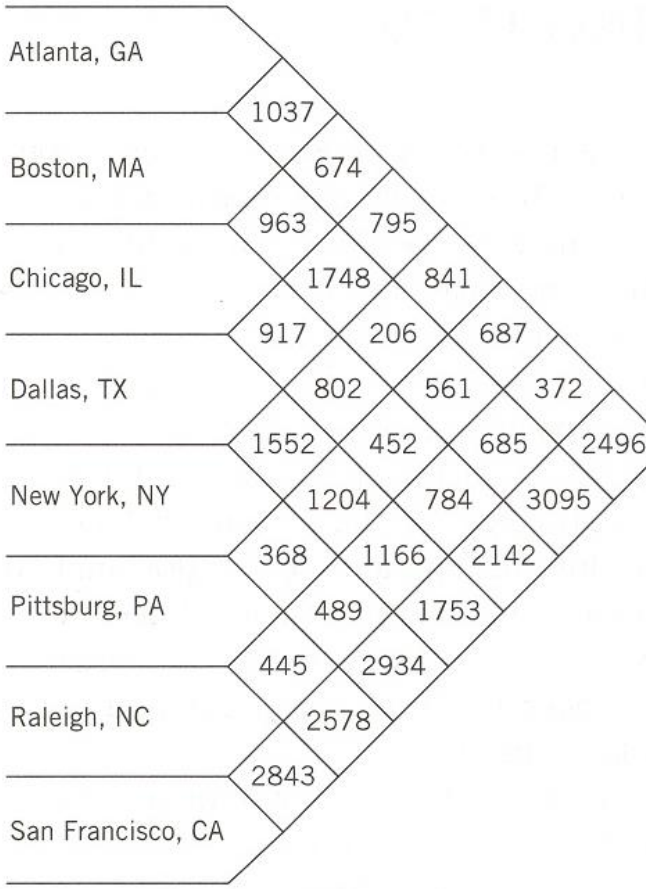


Figure 3.30 Triangular mileage chart.

From-To Chart - procedure

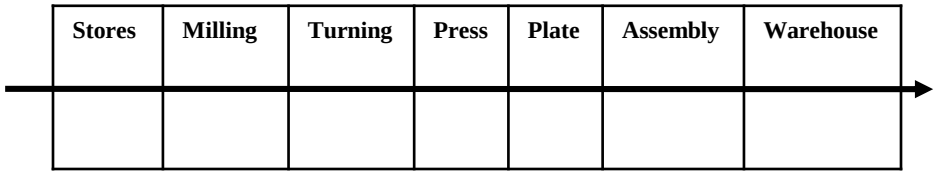
- **List all departments** down the row and across the column following the overall flow pattern.
- **Establish a measure of flow** for the facility that accurately indicates equivalent flow volumes.
  - If the items moved are equivalent (size, weight, value, risk of damage, shape), the measure could be the number of the trips
  - If the items moved vary, then ***equivalent items*** may be established so that the quantities recorded in the From-To Chart represent the proper relationships among the volumes of movement.
- **Record the flow volumes** in the From-To Chart based on the flow paths for the items to be moved and the established measure of flow

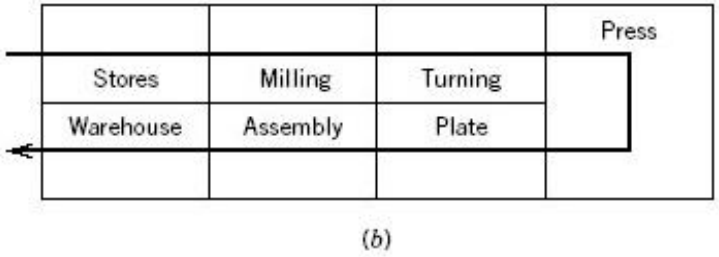
From-To Chart - simple

	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	–	–	–	–	–	–	–

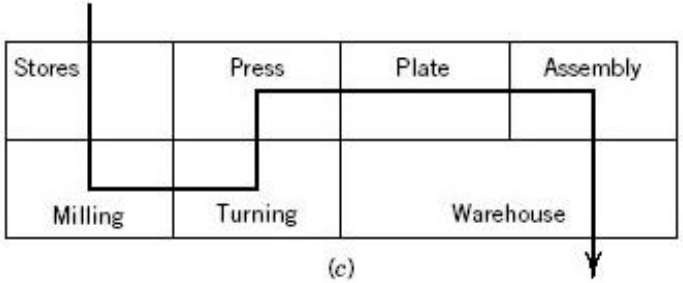
From-To Chart

Possible alternative layouts:

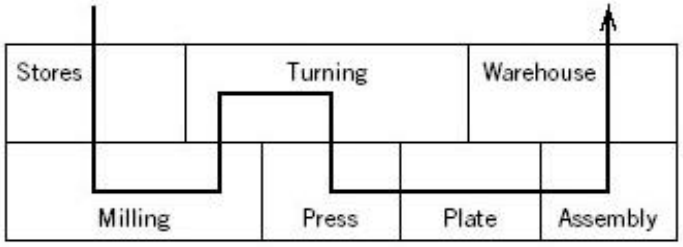




(b)



(c)



(d)

From-To Chart – *Example with equivalent items*

Component	Production Quantity	Routing
1	30	A-C-B-D-E
2	12	A-B-D-E
3	7	A-C-D-B-E

Components 1 and 2 are equivalent with respect to movement, but component 3 is almost twice as large as 1 or 2

Component ID#

Total shipment

Components 1 and 2 are of the same size

Component 3 is twice bigger than the other two

From \ To	A	C	B	D	E
A		① 30 ③2(7) = 14	②12		
		44	12	0	0
C			①30	③2(7) = 14	
	0		30	14	0
B				①30 ②12	③2(7) = 14
	0	0		42	14
D			③2(7) = 14		①30 ②12
	0	0	14		42
E	0	0	0	0	

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	–	–	–	–	–	–	–

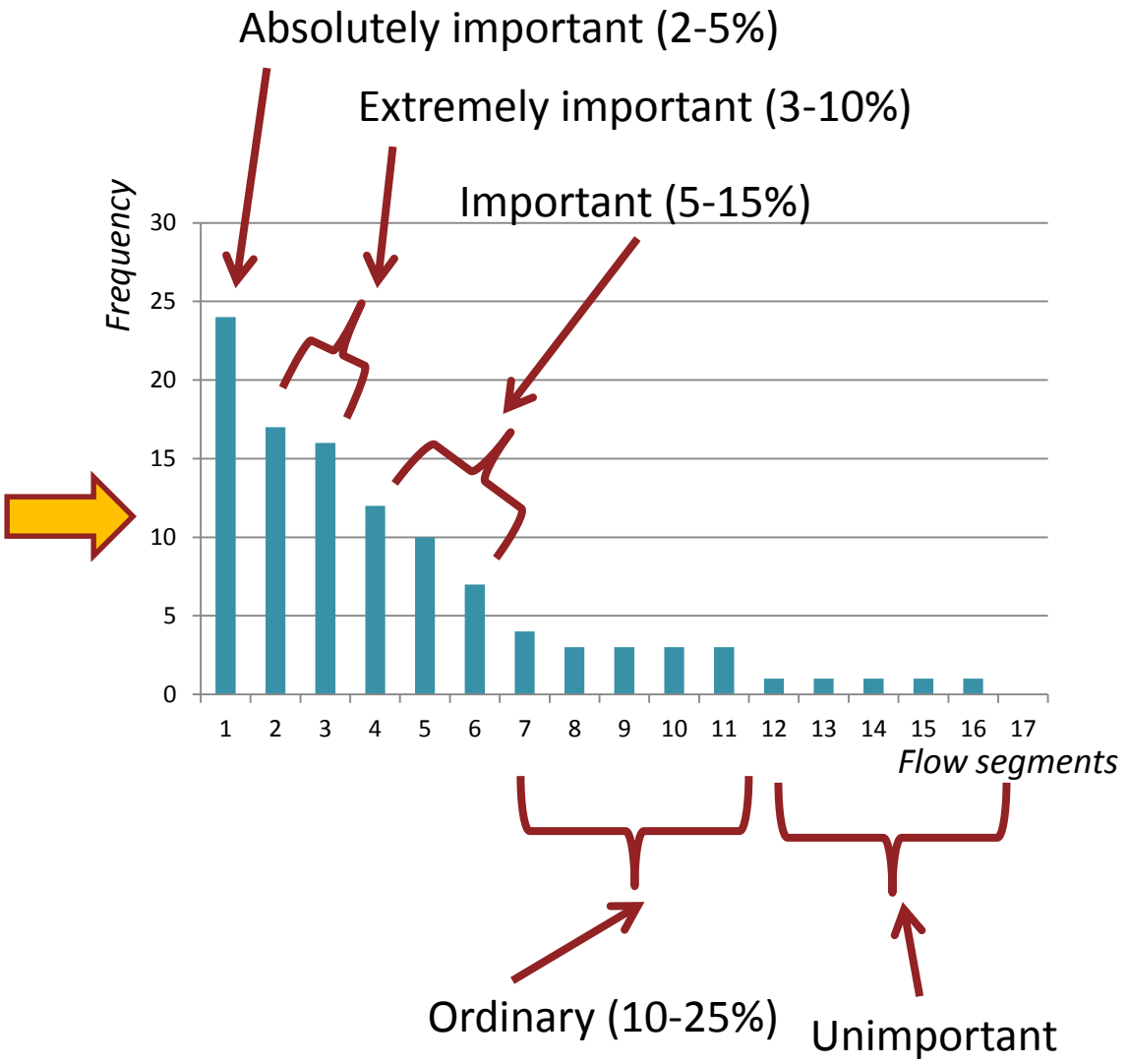
Frequency table

Flow segments	*Departments*	*Frequency*
1	Stores-Milling	24
2	Stores-Turning	12
3	Stores-Press	16
4	Stores-Plate	1
5	Stores-Assembly	8+2=10
6	Milling-Plate	14+3=17
7	Milling-Assembly	3
8	Milling -Warehouse	1
9	Turning- Milling	3
10	Turning-Plate	8+2=10
11	Turning-Warehouse	1
12	Press-Plate	3
13	Press-Assembly	1
14	Press-Warehouse	1
15	Plate-Assembly	4
16	Plate-Warehouse	3
17	Assembly-Warehouse	7

Frequency table

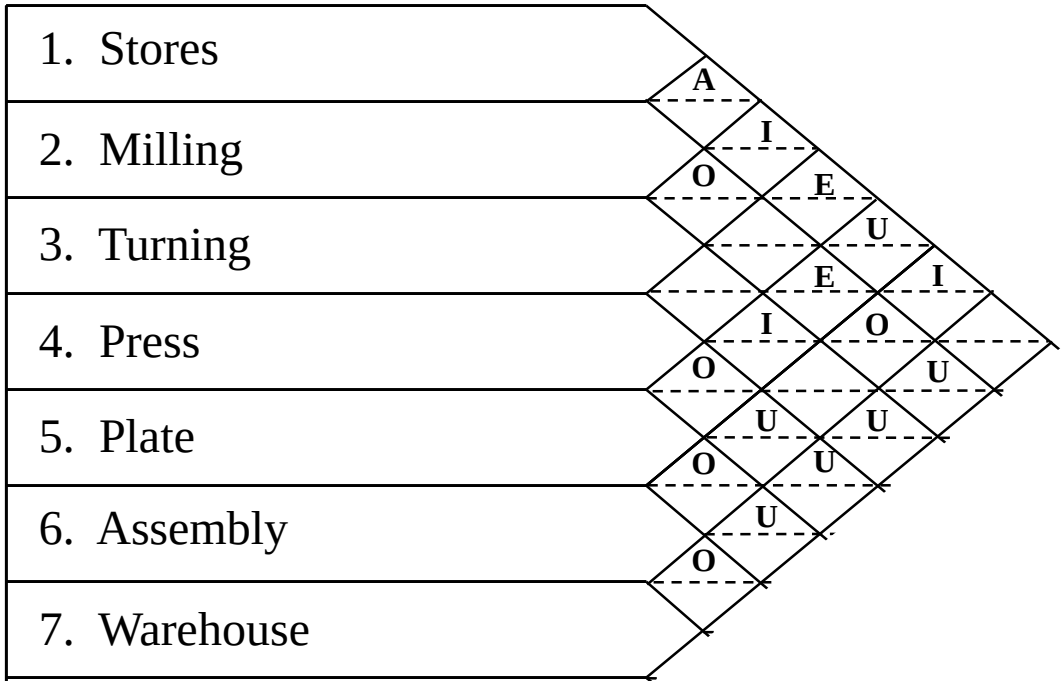
Flow segments	*Departments*	*Frequency*
1	Stores-Milling	24
2	Milling-Plate	14+3=17
3	Stores-Press	16
4	Stores-Turning	12
5	Stores-Assembly	8+2=10
6	Turning-Plate	8+2=10
7	Assembly-Warehouse	7
8	Plate-Assembly	4
9	Milling-Assembly	3
10	Turning- Milling	3
11	Press-Plate	3
12	Plate-Warehouse	3
13	Stores-Plate	1
14	Milling -Warehouse	1
15	Turning-Warehouse	1
16	Press-Assembly	1
17	Press-Warehouse	1

Frequency chart



Relationship Chart

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



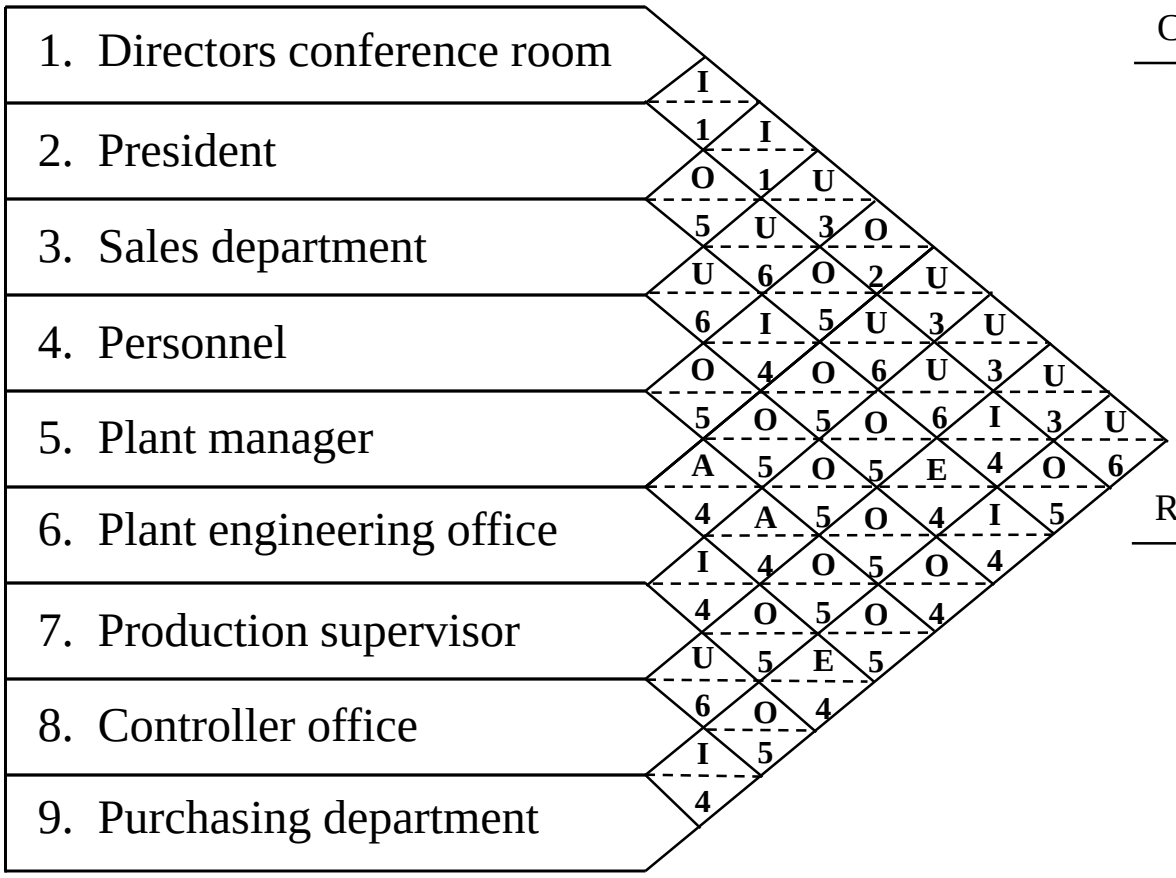
Rating	Definition
A	Absolutely Necessary
E	Especially Important
I	Important
O	Ordinary Closeness
U	Unimportant
X	Undesirable

Relationship Chart

- Due to the great variety and multiplicity of relationships involved, it is advisable to construct separate relationship charts for each major relationship being measured:
  - material flow
  - personnel flow
  - information flow
  - organizational, control, environmental, and process relationships, etc.

Relationship Chart

- Relationship Chart may include the closeness values in conjunction with ***reasons for the value***



Code	Reason
1	Frequency of use high
2	Frequency of use medium
3	Frequency of use low
4	Information flow high
5	Information flow medium
6	Information flow low

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

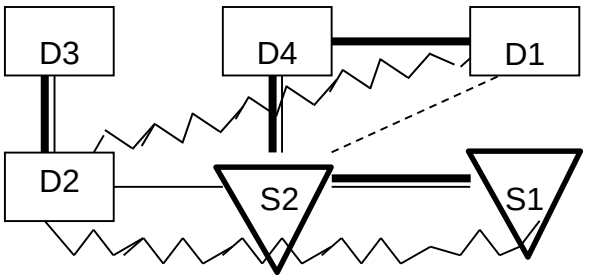
Relationship Diagram

- Transformation of the proximity relationships to a spatial organization of departments

Relationship Chart

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

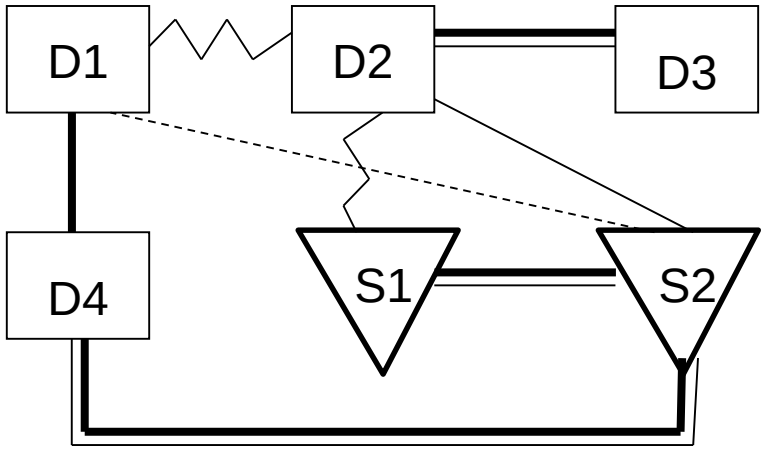
Relationship Diagram



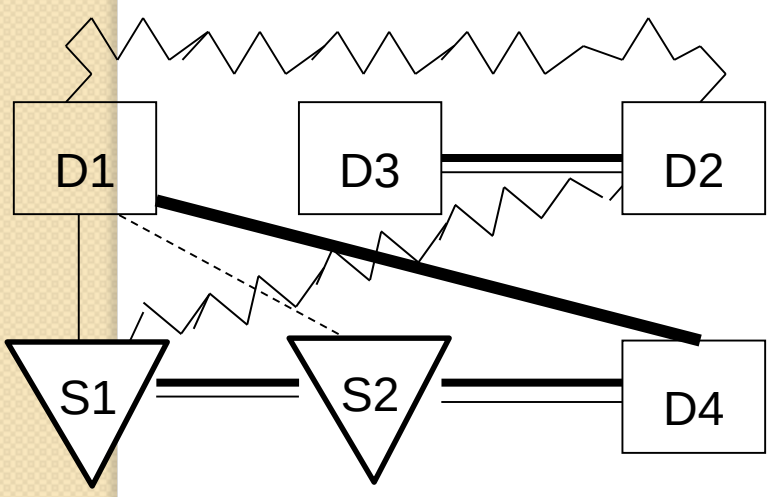
Value	Closeness Priority	Line Code
A	Absolutely important	
E	Specially important	
I	Important	
O	Ordinary	
U	Indiference	
X	Undesireble	

Relationship Diagram

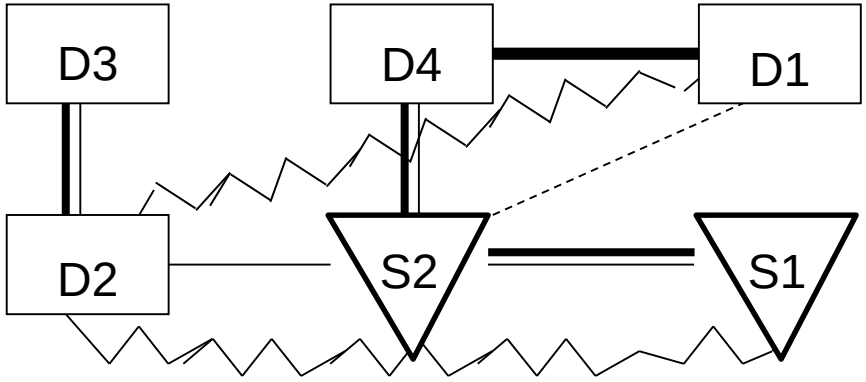
	D1	D2	D3	D4	S1	S2
Dept.1		X	U	E	U	O
Dept.2			A	U	X	I
Dept.3				U	U	U
Dept.4					U	A
Storage 1						A
Storage 2						



Initial Diagram



First iteration



Second iteration (might be the optimum)

Relationship Diagram – systematic procedure

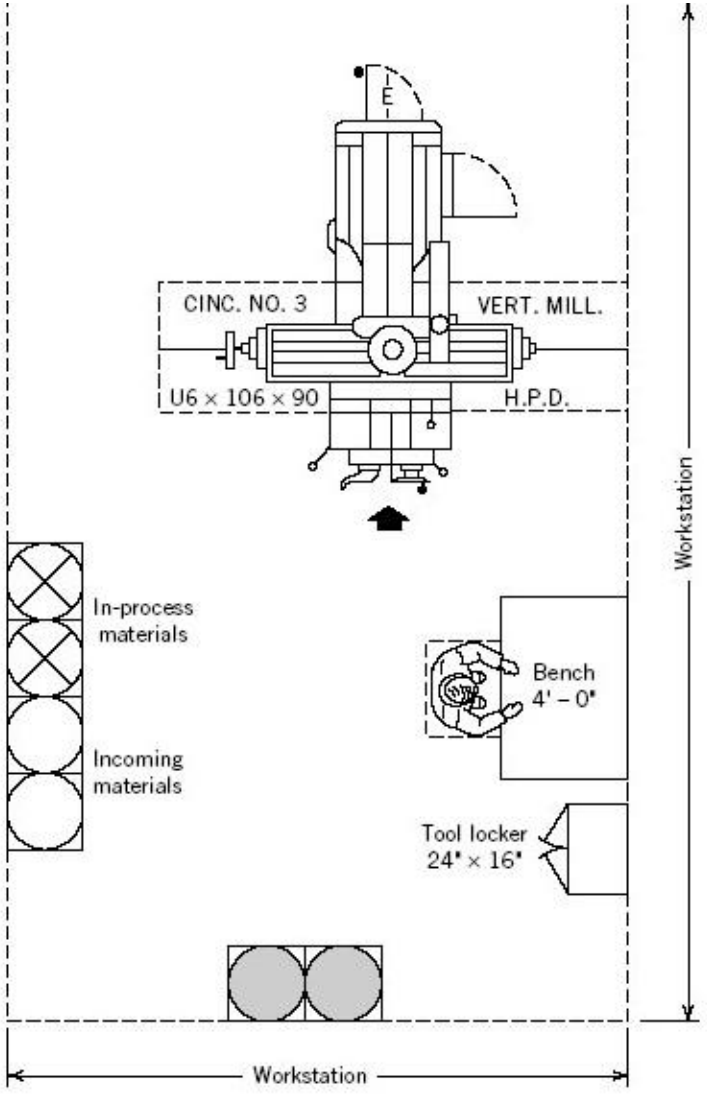
- Place the departments among which there is "**A**" relationship
- Add the departments among which there is "**E**" relationship to the previously placed departments. Rearrange.
- Add the departments among which there is "**X**" relationship to the previously placed departments. Rearrange.
- Add the 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

Space Requirements

- Perhaps the most difficult determination in facilities planning is the amount of space required in the facility!
- Space requirements should be determined:
  - for individual workstations
  - department requirements

Workstation Requirements

- ***Equipment space***
  - The equipment
  - Machine travel
  - Machine maintenance
  - Plant services
- ***Materials space***
  - Receiving and storing materials
  - In-process materials
  - Storing and shipping materials
  - Storing and shipping waste and scrap
  - Tools, fixtures, jigs, dies, and maintenance materials
- ***Personnel area***
  - The operator (motion & ergonomic study)
  - Material handling
  - Operator way in and way out



Departmental Specification

- Once the space requirements for the workstations have been determined, the department space requirements should be defined.
- Departmental area:
  - Sum of areas of workstations
  - Equipment maintenance
  - Tooling, dies, plant services
  - Storage area
  - Spare parts etc.
  - Material handling within department
  - Aisle space

These may be shared!

If the Largest Load Is	Aisle Allowance Percentage Is[a]
Less than 6 ft^2	5-10
Between 6 and 12 ft^2	10-20
Between 12 and 18 ft^2	20-30
Greater than 18 ft^2	30-40

Departmental Specification

- The total area required for the department is determined on Departmental Service and Area Requirement Sheet

DEPARTMENTAL SERVICE AND AREA REQUIREMENT SHEET

Company A.B.C., Inc. Prepared by J.A.
Department Turning Date Sheet 1 of 1

Work Station	Quantity	Service Requirements: Power	Compressed Air	Other	Floor Loading	Ceiling Height	Area (square feet): Equipment	Material	Personnel	Total
Turret lathe	5	440 V AC	10 CFM @ 100 psi		150 PSF	4′	240	100	100	440
Screw machine	6	440 V AC	10 CFM @ 100 psi		190 PSF	4′	280	240	120	640
Chucker	2	440 V AC	10 CFM @ 100 psi		150 PSF	5′	60	100	40	200

Net area required	1280
13% aisle allowance	167
Total area required	1447

Figure 3.36 Department service and area requirements sheet

Next lecture

- Material handling