Facility Layout

Module 8

July 21, 2014

Overview

- What is facility layout?
- Layout strategies
  - ✓ Process layout
  - ✓ Product layout

Last Module…

- We've looked at different methods for selecting a facility

- Now we want to make the best use of every inch of that facility's available space

Definition

- Facility Layout
  - ✓ Arrangement of everything within a facility
    - departments, workgroups, machines, etc.

The goal is to ensure a smooth and efficient work flow…

Take for example a residential house.

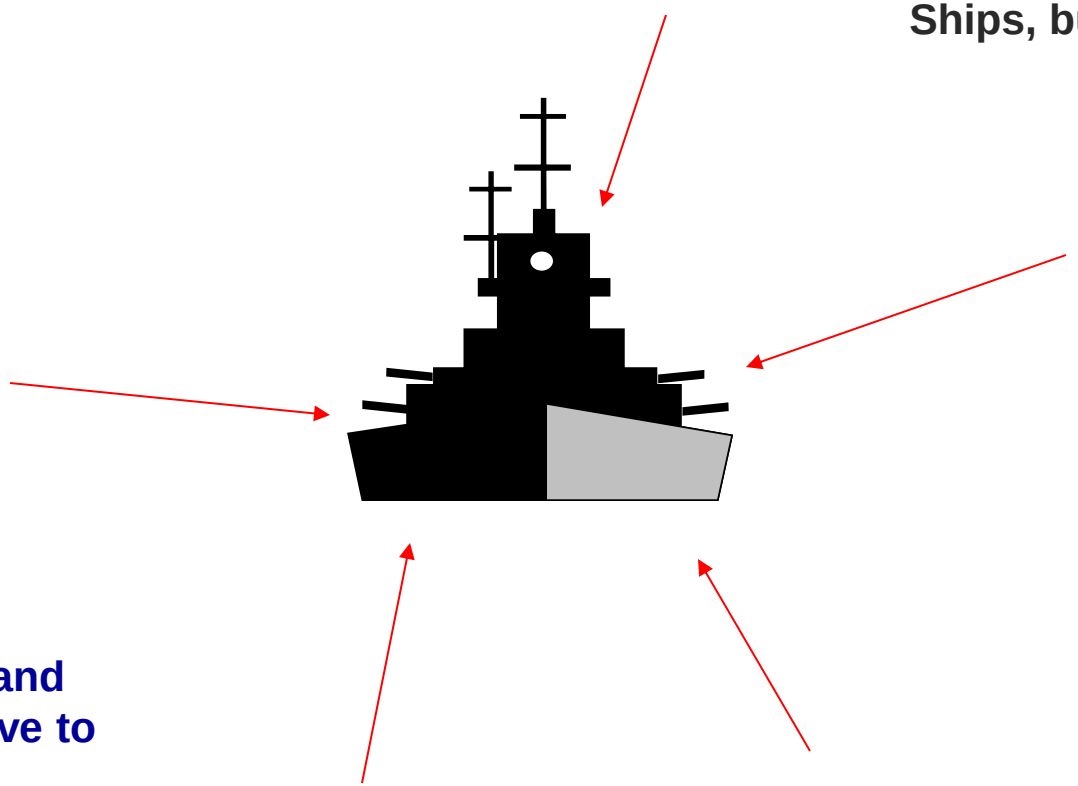
Once you have decided its location, the design of the house is a formidable challenge.

What is it that you would like to achieve with the design of a:

A) House?
B) Kitchen in the house?
C) Grocery store?
D) Department store?
E) Warehouse?
F) Manufacturing plant?
G) Hospital? Doctor's/dentist's office? etc.

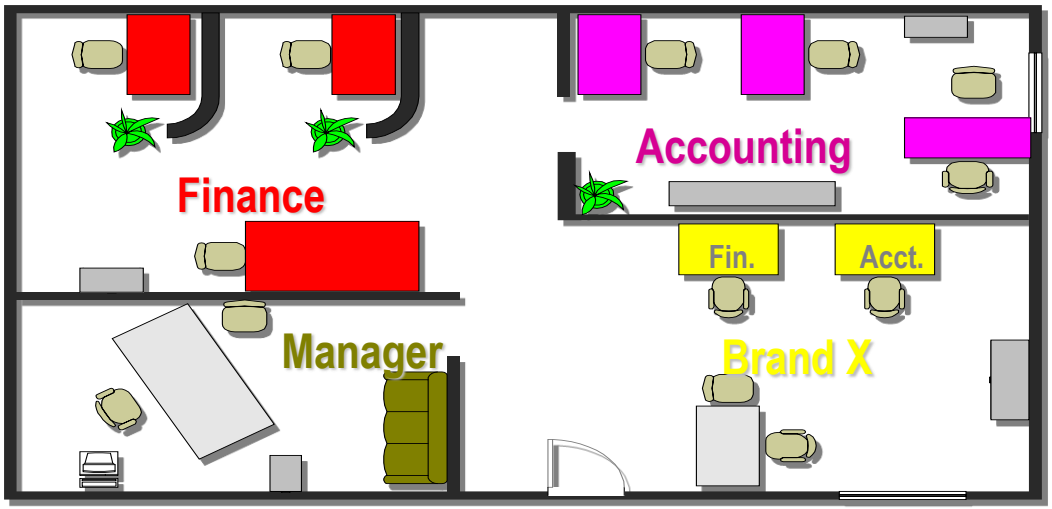
7 Layout Strategies

1. Fixed-position layout
   - ✓ Arranges workers and equipment around large bulky projects



7 Layout Strategies

1. Fixed-position layout
   - ✓ Arranges workers and equipment around large projects (e.g., ships & buildings)
2. Office layout
   - ✓ Positions workers and their equipment for flow of information (CIS building…)



Arranged by process or product

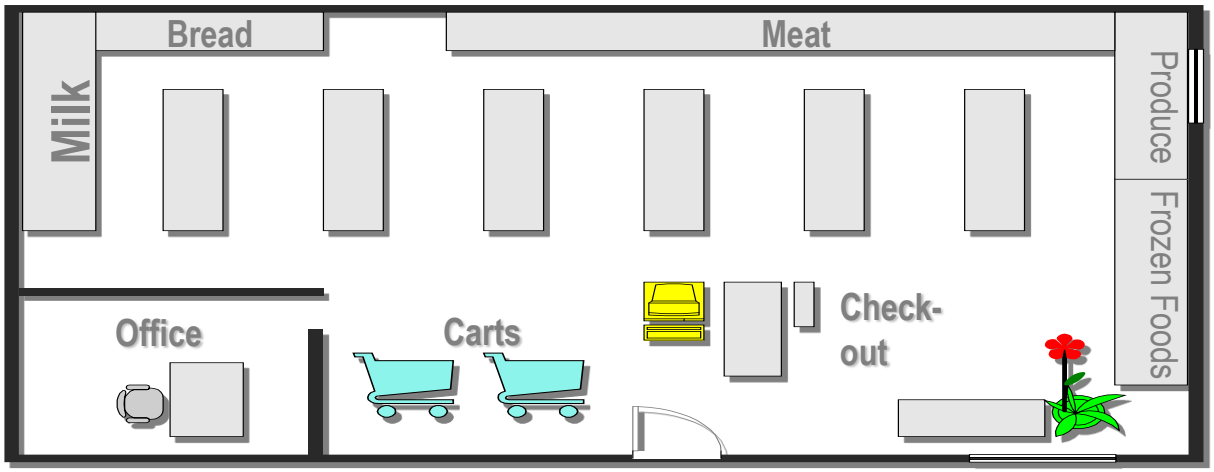
7 Layout Strategies

1. Fixed-position layout
   - ✓ Arranges workers and equipment around large projects (e.g., ships & buildings)
2. Office layout
   - ✓ Positions workers and their equipment for flow of information (CIS building…)
3. Retail layout
   - ✓ Positions products to maximize product exposure & net profit per unit of space (grocery store, department store, hardware store…)

High-draw items around the periphery of the store

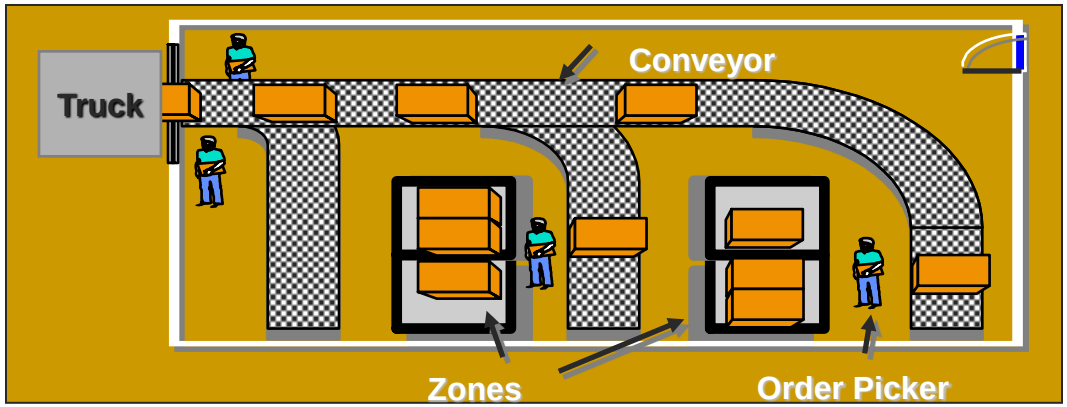
No cross-over isles

End isle locations used for high exposure

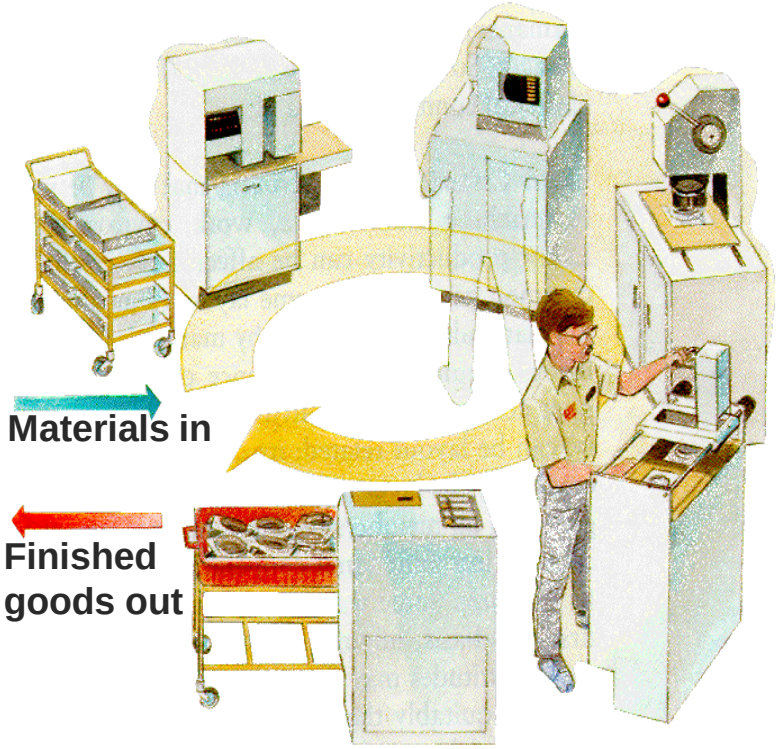


7 Layout Strategies

1. Fixed-position layout
   - ✓ Arranges workers and equipment around large projects (e.g., ships & buildings)
2. Office layout
   - ✓ positions workers and their equipment for flow of information (CIS building…)
3. Retail layout
   - ✓ positions products to maximize product exposure & net profit per unit of spacePositions products to maximize product exposure & net profit per unit of space (grocery store, department store, hardware store…)
4. Warehouse layout
   - ✓ Positions products according to trade-offs between material handling & space



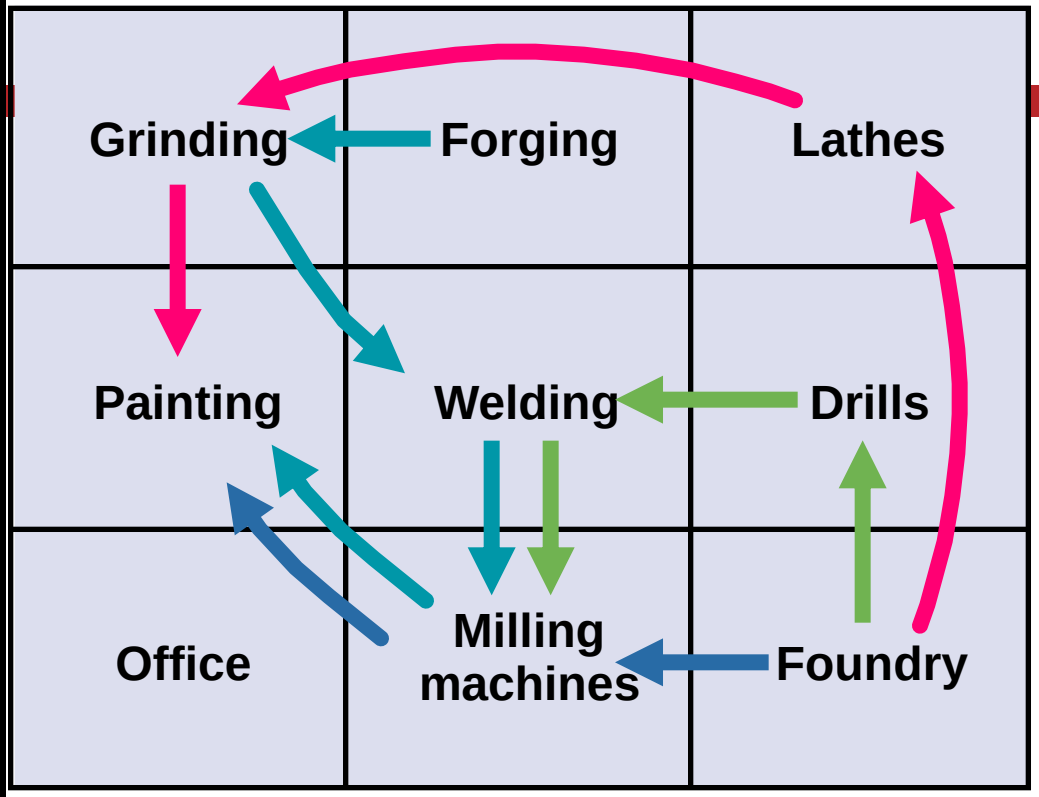
7 Layout Strategies



1. Fixed-position layout
   - ✓ Arranges workers and equipment aro
2. Office layout
   - ✓ positions workers and their equipmen
3. Retail layout
   - ✓ positions products to maximize produ
4. Warehouse layout
   - ✓ Positions products according to trade
5. Group technology (cellular) layout
   - ✓ Sets up small cells of machines & workers. Each cell produces family of products
6. Process layout (*also called job shop layout*)
   - ✓ Positions departments or work centers in lo-volume, hi-variety production environments to minimize handling costs (hospital, auto repair shop…)
7. Product layout (*also called assembly line layout*)
   - ✓ Deals with setting up assembly lines in high-volume, low-variety production environments to balance work among workstations

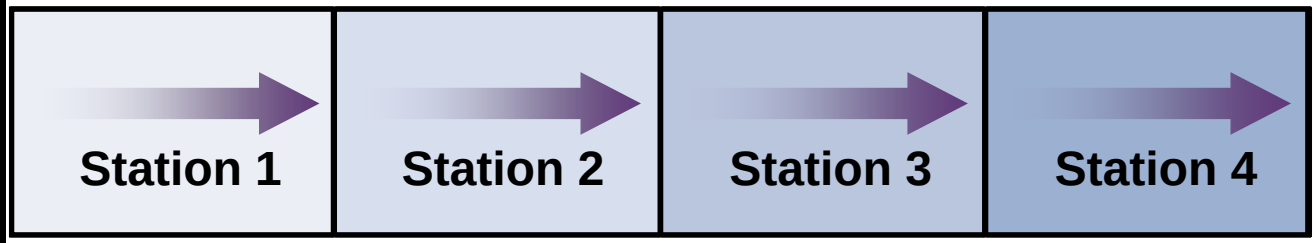
We will cover these layout strategies in more detail…

Process/Product Layout Types



PROCESS LAYOUT

(a) Layout of a job shop



PRODUCT LAYOUT

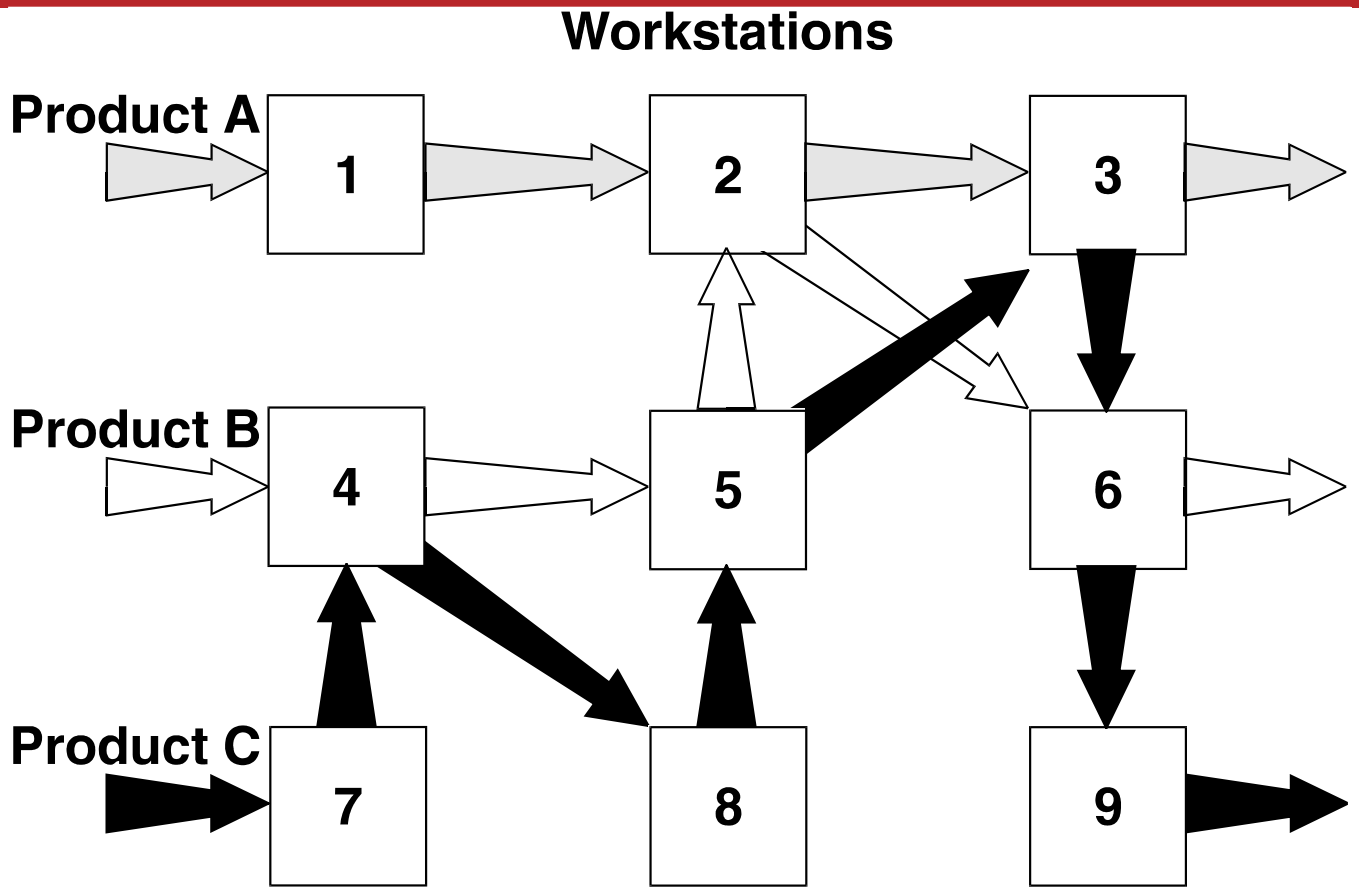
(b) Layout of a production line

Process Layout

- **Workstations are physically organized according to the operations they perform**
  - ✓ All drilling machines located in the drilling department
  - ✓ All accountants located in the accounting department

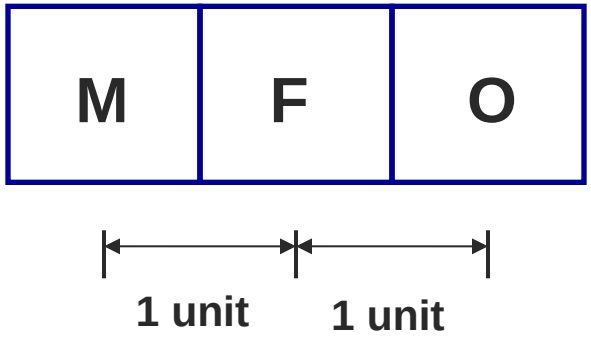
How should we position our workstations throughout the facility??

Process Layout



Process Layout: Load-Distance Analysis Example 1

- **Suppose we have 3 rooms in our building**



average distance between rooms

	M	F	O
M	-	5	30
F		-	20
O			-

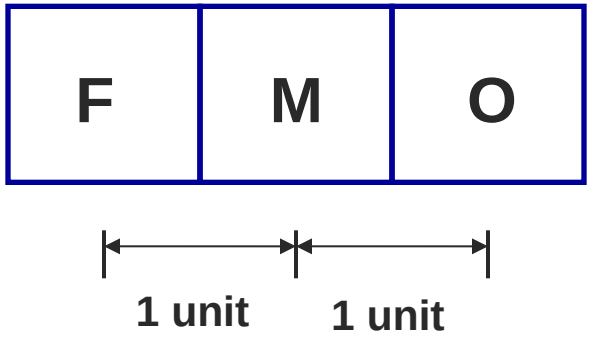
"Load Matrix"

expected # of times people move between departments

- **How should we position the Marketing, Finance, and Operations departments across these rooms?**

Process Layout: Load–Distance Analysis Example 1

- **Suppose we have 3 rooms in our building**



average distance between rooms

	M	F	O
M	-	5	30
F		-	20
O			-

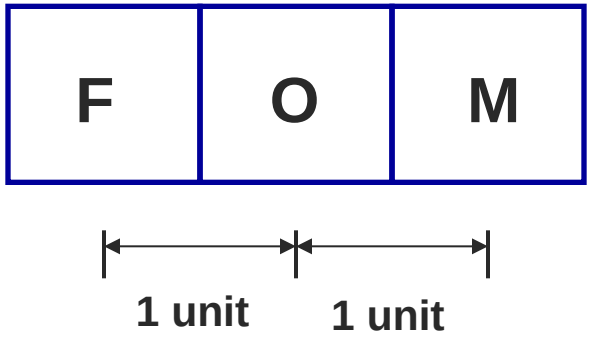
"Load Matrix"

expected # of times people move between departments

- **How should we position the Marketing, Finance, and Operations departments across these rooms?**

Process Layout: Load-Distance Analysis Example 1

- **Suppose we have 3 rooms in our building**



average distance between rooms

	M	F	O
M	-	5	30
F		-	20
O			-

"Load Matrix"

expected # of times people move between departments

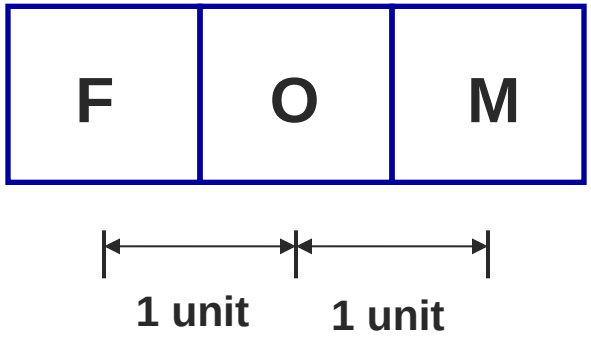
- **How should we position the Marketing, Finance, and Operations departments across these rooms?**

Total # of ways to arrange 3 departments across 3 rooms?

3! = (3)(2)(1) = 6

Process Layout: Load-Distance Analysis Example 1

- **Suppose we have 3 rooms in our building**



average distance between rooms

	M	F	O
M	-	5	30
F		-	20
O			-

"Load Matrix"

expected # of times people move between departments

How much does this configuration cost if each move costs $5/unit distance?

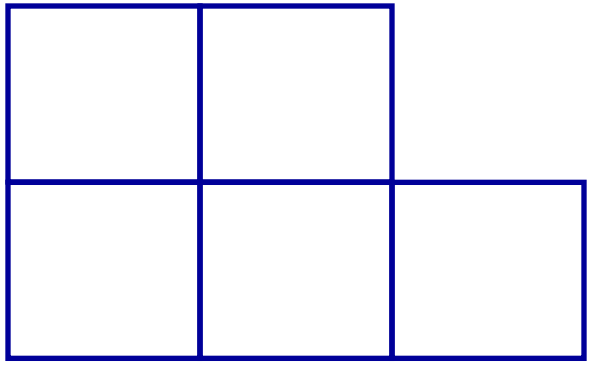
Pair	Load	Distance	(Load)(Dist.)	Cost
M-F	5	2	(5)(2) = 10	(10)(5) = 50
M-O	30	1	30	150
F-O	20	1	20	100
				$300 Total Cost

Is this the lowest cost option?

Process Layout: Load Distance Analysis - Example 2

A: receptionist
B: waiting room
C: x-ray
D: exam room
E: nurse station

- What if we have 5 hospital departments:
- And our floor area looks like this:



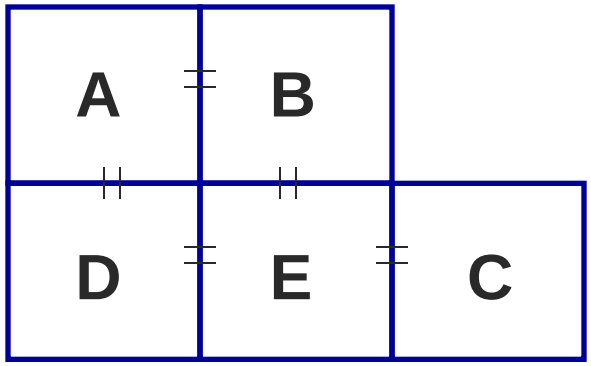
	A	B	C	D	E
A	-	5	2	4	1
B		-	3	0	2
C			-	0	0
D				-	5
E					-

Loads could be the average number of patients that move between the departments each hour.

Process Layout: Load-Distance Analysis - Example 2

A: receptionist
B: waiting room
C: x-ray
D: exam room
E: nurse station

- What if we have 5 hospital departments:
- And our floor area looks like this:



	A	B	C	D	E
A	-	5	2	4	1
B		-	3	0	2
C			-	0	0
D				-	5
E					-

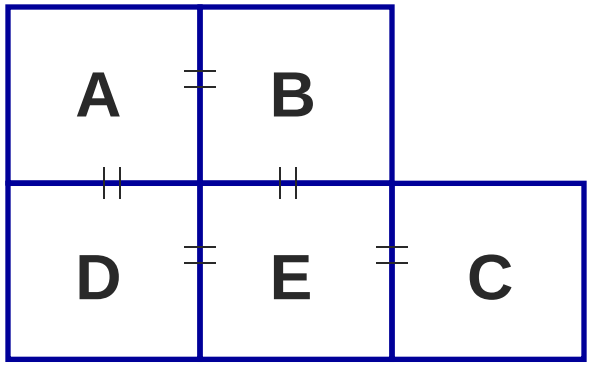
Assume that workers can't move diagonally (through walls)

Which departments should you try to keep close together?

Process Layout: Load-Distance Analysis - Example 2

A: receptionist
B: waiting room
C: x-ray
D: exam room
E: nurse station

- What if we have 5 hospital departments:
- And our floor area looks like this:



	A	B	C	D	E
A	-	5	2	4	1
B		-	3	0	2
C			-	0	0
D				-	5
E					-

Pair	Load	Distance	(Load)(Dist.)	Cost
A-B	5	1	(5)(1) = 5	(5)(.1) = .5
A-C	2	3	6	.6
A-D	4	1	4	.4
A-E	1	2	2	.2
B-C	3	2	6	.6
B-D	0	2	0	0
B-E	2	1	2	.2
C-D	0	2	0	0
C-E	0	1	0	0
D-E	5	1	5	.5

Total Cost
$3.00

Hourly Cost?

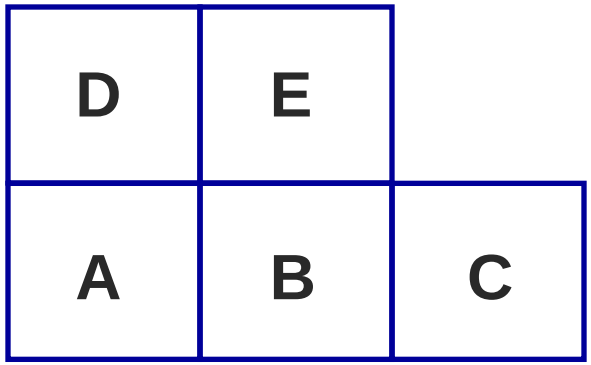
Can we do better?

Assuming it costs $0.10/ unit moved each unit distance

Process Layout: Load-Distance Analysis - Example 2

A: receptionist
B: waiting room
C: x-ray
D: exam room
E: nurse station

- What if we have 5 hospital departments:
- And our floor area looks like this:



	A	B	C	D	E
A	-	5	2	4	1
B		-	3	0	2
C			-	0	0
D				-	5
E					-

Pair	Load	Distance	(Load)(Dist.)	Cost
A-B	5	1	5	.5
A-C	2	2	4	.4
A-D	4	1	4	.4
A-E	1	2	2	.2
B-C	3	1	3	.3
B-D	0	2	0	0
B-E	2	1	2	.2
C-D	0	3	0	0
C-E	0	2	0	0
D-E	5	1	5	.5

Total Cost
$2.50

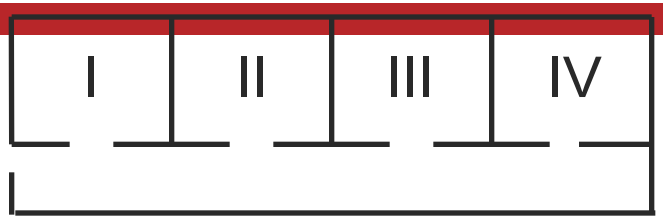
Can we find a better solution?

Process Layout: Load Distance Analysis- Example 3

Smiley-face Dental clinic needs to locate four departments (waiting room (W), check-up room (C), laboratory (L), and surgery (S)) in four areas (I, II, III and IV).

The owner wants to minimize the interdepartmental transportation costs associated with his nurses escorting patients, which he expects to be $0.10 per patient per yard.

The following information is given.



Distance Matrix in yards

	I	II	III	IV
I	---	10	20	30
II		---	10	20
III			---	10
IV				---

Load Matrix (trips per week)

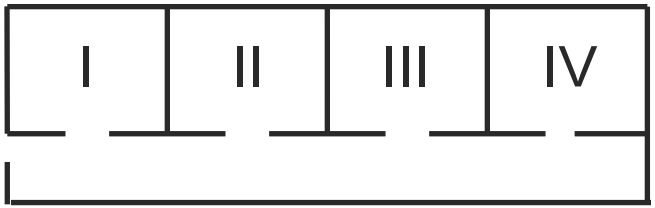
	Waiting(W)	Check-up(C)	Lab(L)	Surgery(S)
Waiting (W)	----			
Check-up (C)	200	---		
Lab (L)	50	40	---	
Surgery (S)	25	10	2	---

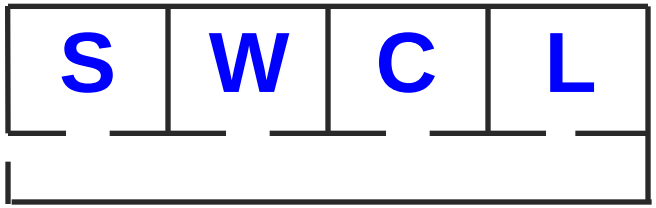
Distance Matrix in yards

	I	II	III	IV
I	---	10	20	30
II		---	10	20
III			---	10
IV				---

Load Matrix (trips per week)

	Waiting (W)	Check-Up (C)	Lab (L)	Surgery (S)
Waiting (W)	----			
Check-up (C)	200	---		
Lab (L)	50	40	---	
Surgery (S)	25	10	2	---





What are the weekly total costs for the least costly process layout?

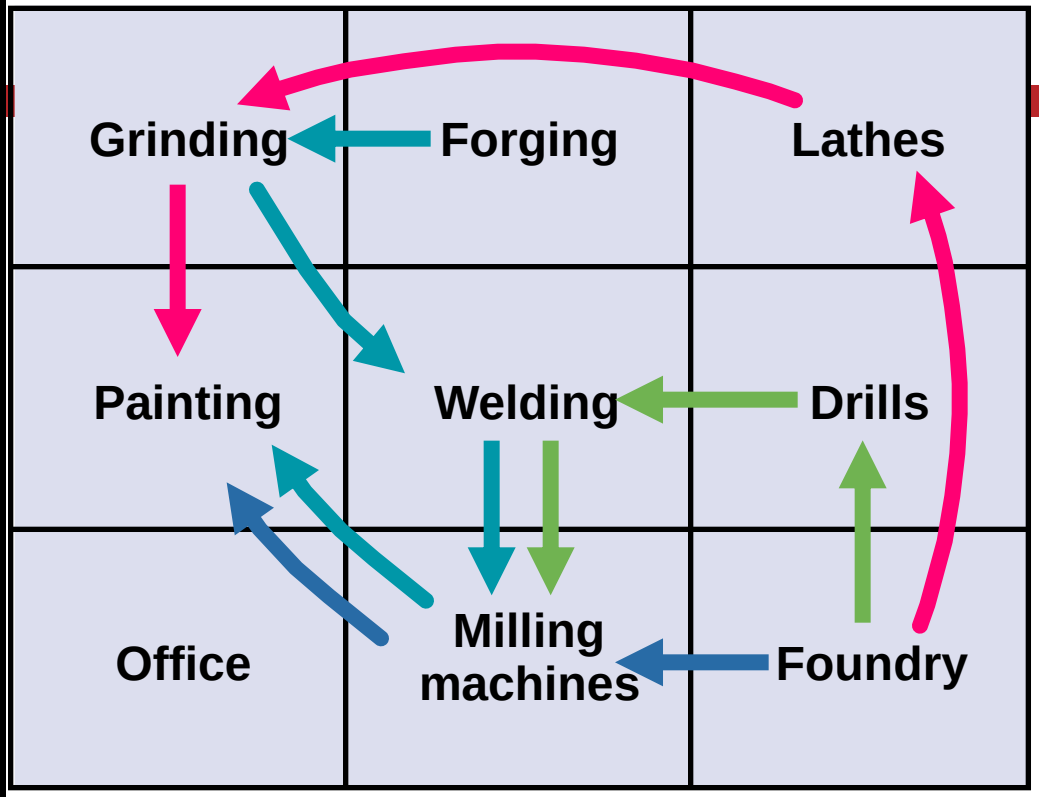
Pair	Load	Distance	LD	Cost per unit	Cost
C-W	200	10	2,000	$0.10	$200
L-W	50	20	1,000	$0.10	$100
L-C	40	10	400	$0.10	$40
S-W	25	10	250	$0.10	$25
S-C	10	20	200	$0.10	$20
S-L	2	30	60	$0.10	$6
					$391

Process Layout

- Many software packages are available
  - ✓ CRAFT (Computerized Re-Allocation of Facilities Technique)
  - ✓ SPACECRAFT (A more advanced version of CRAFT)
  - ✓ ALDEP (Automated Layout Design Program)
  - ✓ CORELAP (Computerized Relationship Layout Planning)

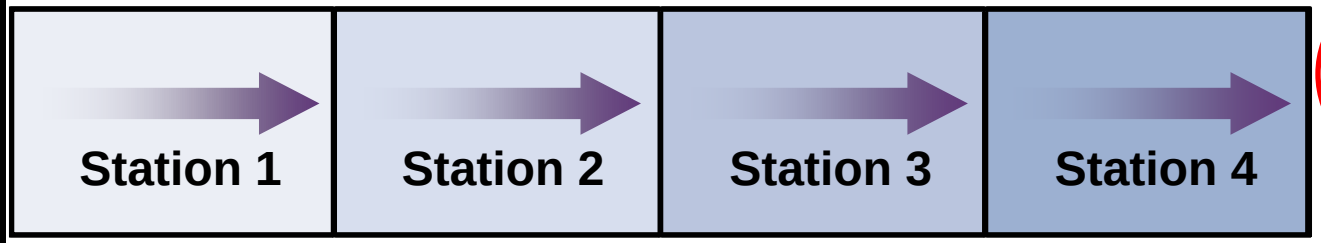
- Most seek the layout that minimizes:
  (Load x Distance)

Process/Product Layout Types



PROCESS LAYOUT

(a) Layout of a job shop



PRODUCT LAYOUT

(b) Layout of a production line

Product Layout

- Workstations are organized in lines making specific products
  - ✓ e.g., one drilling machine in the assembly line making ipod cases

Assembly Line: Ford Model T

Assembly Line (Product layout)

JEEP LIBERTY

Production of Jeep Liberty and Dodge Nitro models was halted yesterday. The Toledo plant normally turns out about 1,200 of the two in a day. Plastech manufactures 70 to 80 parts for the Liberty and Nitro.

DODGE NITRO

The Blade

JEEP WRANGLER

THE BLADE

Some Jeep Wranglers are still being built despite Chrysler's impasse with one of its main suppliers. Normally about 580 Wranglers are made in a day. Frank Smaciarz is shown installing trim on a Wrangler in 2007.

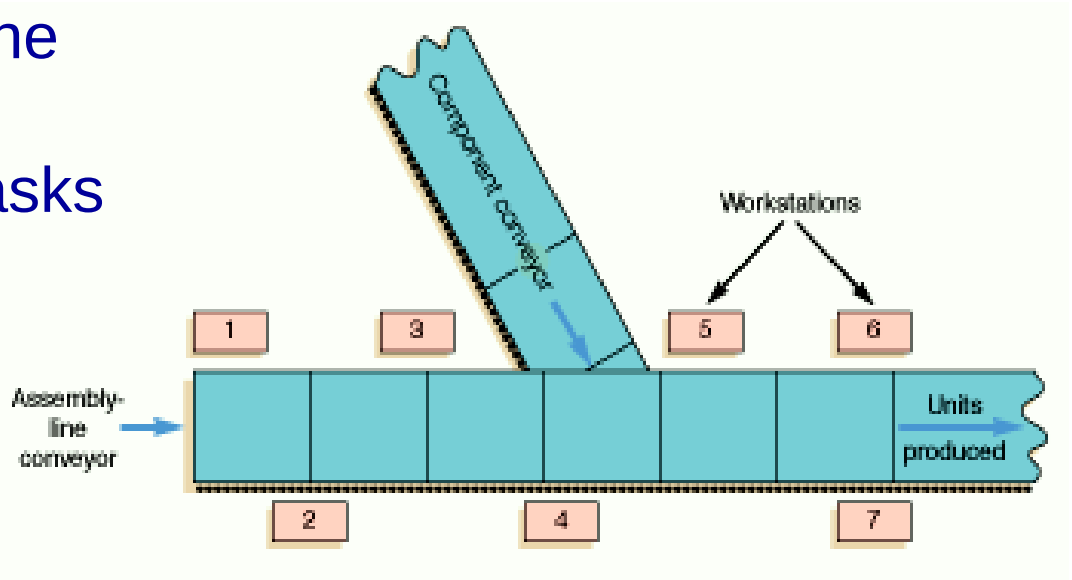
Making Chocolates…..

Product Layout: Primary Question

- How should we assign tasks to workstations?

bits of work performed at a workstation

locations where one or more workers perform a set of tasks



Goal is to balance work across the workstations.

Advantages of Product Layout

- ✓ Little work-in-process inventory
- ✓ Short throughput and manufacturing lead times (shorter cash cycle)
- ✓ Lower unit cost

Assembly Line Balancing – Example 1

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

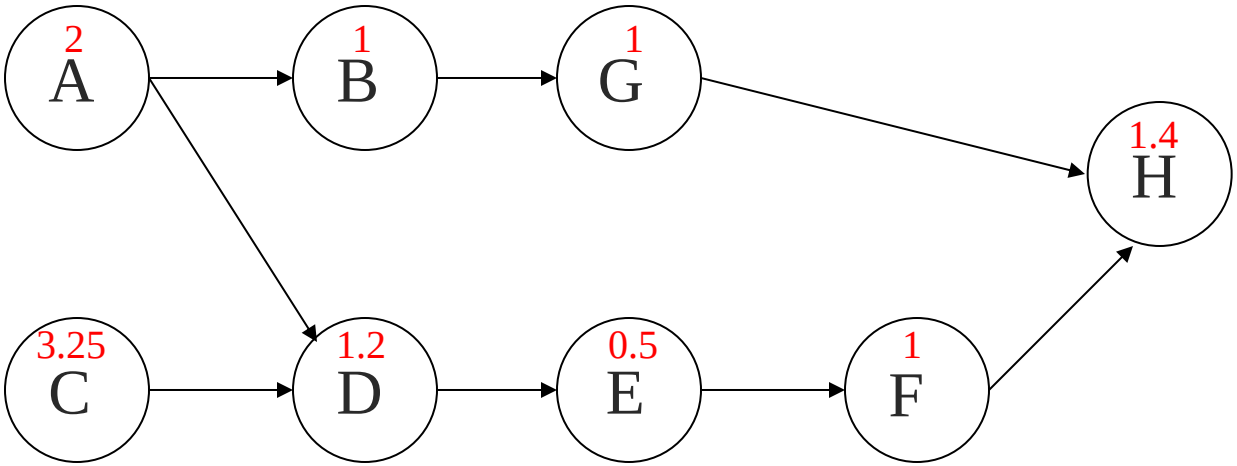
Task	Time (Mins)	Description	Predecessors
A	2	Assemble frame	None
B	1	Mount switch	A
C	3.25	Assemble motor housing	None
D	1.2	Mount motor housing in frame	A, C
E	0.5	Attach blade	D
F	1	Assemble and attach safety grill	E
G	1	Attach cord	B
H	1.4	Test	F, G

Precedence Diagram

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

Question: What is the time between successive units coming off the line?

"Cycle Time"

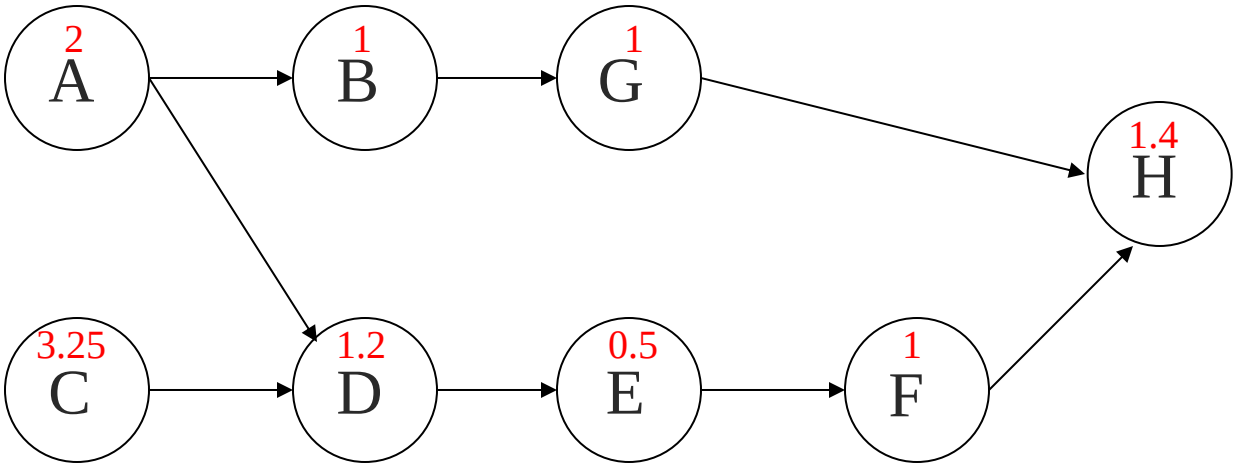


Answer: 3.25 minutes

Production Rate

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

Question: How many units will be produced per hour?



$$\text{Production Rate} = \frac{1}{\text{cycle time}} = \frac{1 \text{ unit}}{3.25 \text{ min}} \times \frac{60 \text{ min}}{1 \text{ hr}} = 18.46 \text{ units/hr}$$

Example 1

Min number workstations

Task	Time (Mins)
A	2
B	1
C	3.25
D	1.2
E	0.5
F	1
G	1
H	1.4

T = 11.35 min

What is the theoretical minimum number of workstations that we can have on the assembly line to achieve the 4 minute cycle time?

$$N_{min} = \left\lceil \frac{\text{Sum of task times (T)}}{\text{Cycle time (C)}} \right\rceil = \left\lceil \frac{11.35}{4} \right\rceil = \lceil 2.84 \rceil = 3$$

Now let's try to improve the efficiency of our line by dividing the tasks among workstations

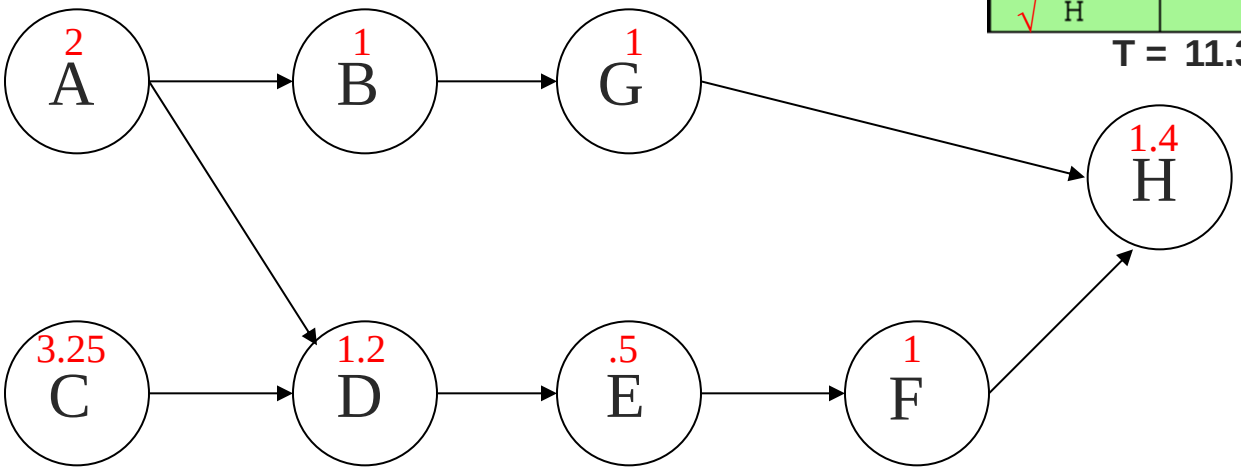
Methods to groups tasks into workstations

1. Longest task time (LTT)
   - Assign feasible task with greatest task time
2. Largest number of following tasks (NFT)
   - Assign feasible task with largest # of tasks following it
3. Ranked positional weight (RPW)
   - Assign the task with the highest positional weight
4. Shortest task time (STT)
   - Assign feasible task with the shortest task time

1. Longest Task Time

Task	Time (Mins)	Predecessors
√ A	2	None
√ B	1	A
√ C	3.25	None
√ D	1.2	A, C
√ E	0.5	D
√ F	1	E
√ G	1	B
√ H	1.4	F, G

T = 11.35 min



cycle time$_{max}$ = 4

Time @ Station:

Workstation 1	Workstation 2	Workstation 3	Workstation 4
3.25	CT = 3.7	3	1.4
C (3.25)	A (2)	B (1)	H (1.4)
~~A (2)~~	~~D (1.2)~~	F (1)	
	~~B (1)~~	G (1)	
	E (.5)	~~H (1.4)~~	
	~~F (1)~~		

3.25+2 = 5.25 > 4

2+1.2+1=4.2 > 4

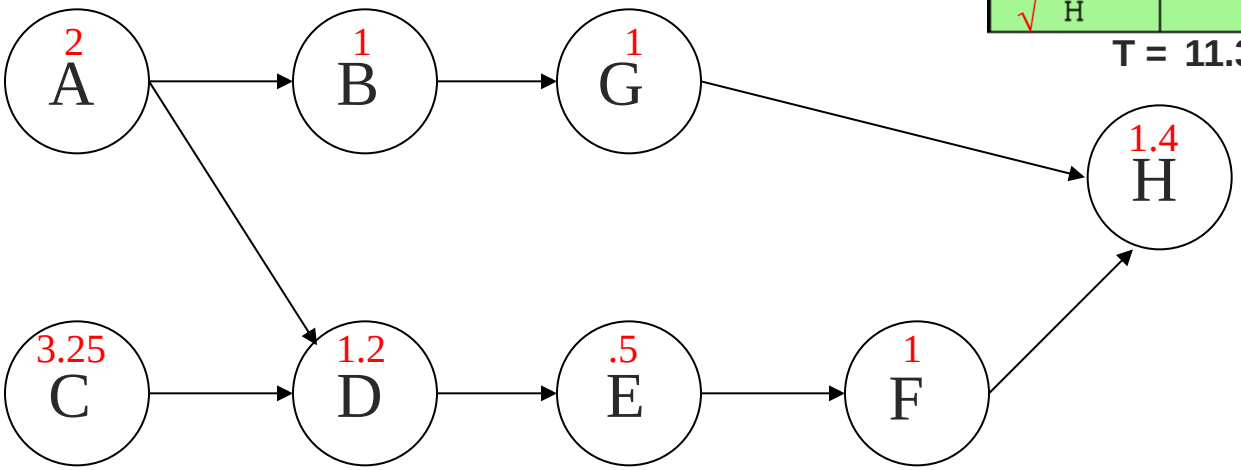
2+1.2+.5+1=4.7 > 4

1+1+1+1.4=4.4 > 4

1. Longest Task Time

Task	Time (Mins)	Predecessors
√ A	2	None
√ B	1	A
√ C	3.25	None
√ D	1.2	A, C
√ E	0.5	D
√ F	1	E
√ G	1	B
√ H	1.4	F, G

T = 11.35 min



cycle time$_{max}$ = 4

Time @ Station:

Workstation 1	Workstation 2	Workstation 3	Workstation 4
3.25	CT = 3.7	3	1.4
C (3.25)	A (2)	B (1)	H (1.4)
~~A (2)~~	~~D (1.2)~~	~~F (1)~~	
	~~B (1)~~	~~G (1)~~	
	E (.5)	~~H (1.4)~~	
	~~F (1)~~		

$$\text{efficiency (of this layout)} = \frac{\text{Sum of task times}}{(\#\text{stations})(\text{max station time})}$$

$$= 11.35/(4 \times 3.7) = 0.767$$

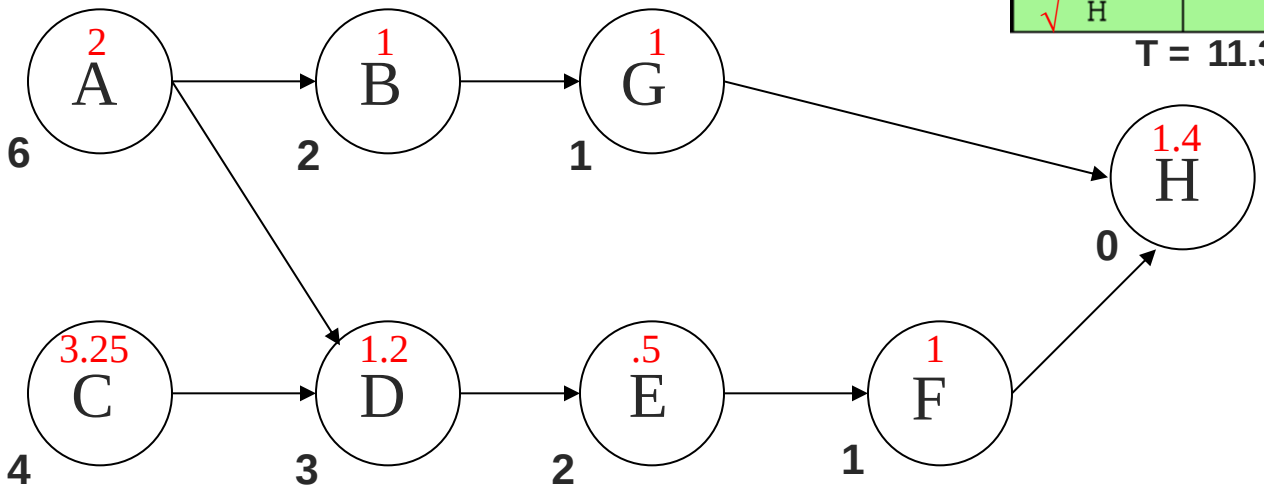
Methods to groups tasks into workstations

1. Longest task time (LTT)
   - Assign feasible task with greatest task time
2. Largest number of following tasks (NFT)
   - Assign feasible task with largest # of tasks following it
3. Ranked positional weight (RPW)
   - Assign the task with the highest positional weight
4. Shortest task time (STT)
   - Assign feasible task with the shortest task time

2. Largest # of Following Task

Task	Time (Mins)	Predecessors
√ A	2	None
√ B	1	A
√ C	3.25	None
√ D	1.2	A, C
√ E	0.5	D
√ F	1	E
√ G	1	B
√ H	1.4	F, G

T = 11.35 min



cycle time$_{max}$ = 4

Time @ Station:

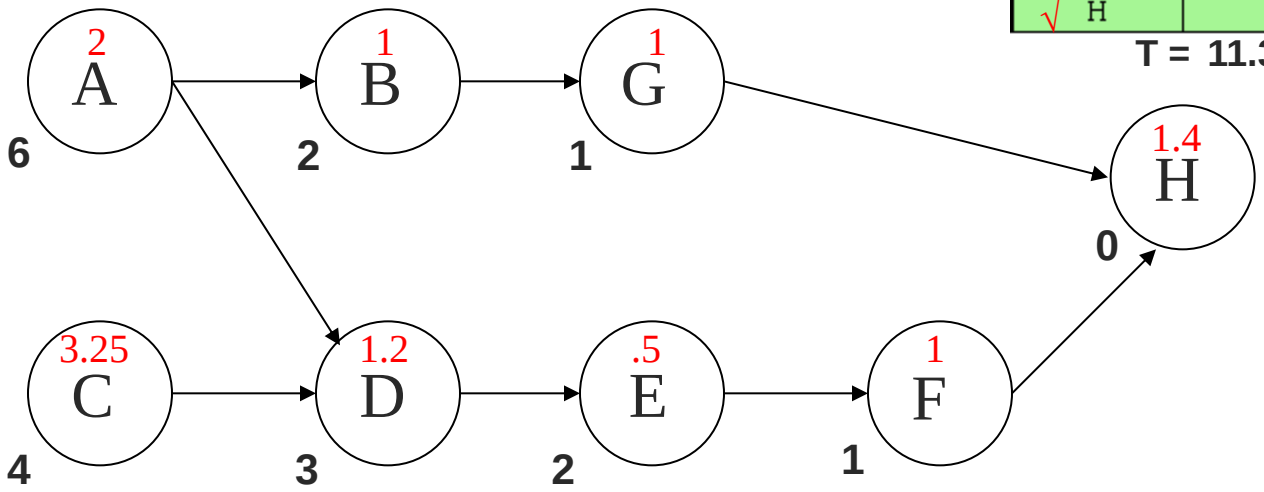
Workstation 1	Workstation 2	Workstation 3	Workstation 4
4 = CT	3.25	2.7	1.4
A (2)	C (3.25)	D (1.2)	H (1.4)
~~C (3.25)~~	~~D (1.2)~~	E (.5)	
B (1)		F (1)	
G (1)		~~H (1.4)~~	

2+3.25=5.25 > 4 3.25+1.2 = 4.45 > 4 1.2+.5+1+1.4 = 4.1 > 4

2. Largest # of Following Task

Task	Time (Mins)	Predecessors
√ A	2	None
√ B	1	A
√ C	3.25	None
√ D	1.2	A, C
√ E	0.5	D
√ F	1	E
√ G	1	B
√ H	1.4	F, G

T = 11.35 min



cycle time$_{max}$ = 4

Time @ Station:

Workstation 1	Workstation 2	Workstation 3	Workstation 4
4 = CT	3.25	2.7	1.4
A (2)	C (3.25)	D (1.2)	H (1.4)
~~C (3.25)~~	~~D (1.2)~~	E (.5)	
B (1)		F (1)	
G (1)		~~H (1.4)~~	

$$\text{efficiency} = \frac{\text{Sum of task times}}{(\#\text{stations})(\text{max station time})}$$

$$= 11.35/(4 \times 4) = 0.709$$

Methods to groups tasks into workstations

1. Longest task time (LTT)
   - Assign feasible task with greatest task time
2. Largest number of following tasks (NFT)
   - Assign feasible task with largest # of tasks following it
3. Ranked positional weight (RPW)
   - Assign the task with the highest positional weight
4. Shortest task time (STT)
   - Assign feasible task with the shortest task time

Summary

Task	Description
A	Assemble frame
B	Mount switch
C	Assemble motor housing
D	Mount motor housing in frame
E	Attach blade
F	Assemble and attach safety grill
G	Attach cord
H	Test

	station 1	station 2	station 3	station 4
LTT	C	ADE	BFG	H
NFT	ABG	C	DEF	H

Which layout is best?

Associated production rates?

Notice that none of our solutions yielded the theoretical minimum number of stations

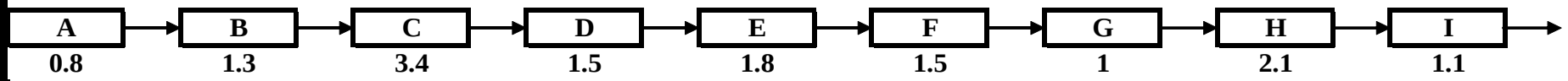
Assembly Line Balancing –

Suppose that the following nine tasks are required to make one item; but that the tasks have precedence relationships.

Task	Preceded by	Time (minutes)
A	-	0.8
B	A	1.3
C	A	3.4
D	-	1.5
E	B	1.8
F	C,D	1.5
G	E	1.0
H	E,F	2.1
I	G,H	1.1

	Total	14.5

Suppose that each of these tasks is performed in a separate Work Station like in the Assembly Line shown below:



Does this line meet all the precedence requirements?

Yes

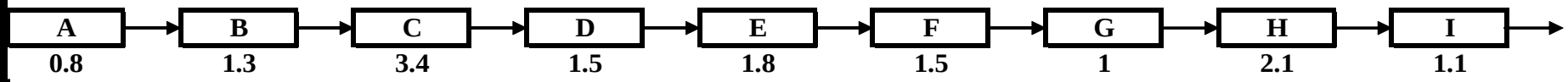
The cycle time for the above line will be:

One unit every 3.4 minutes

The corresponding production rate will be:

60 / 3.4 = 17.65 units per hour

The efficiency (E) of an assembly line is given by the following formula:



$$E = \frac{\sum \text{Task Time}}{(\text{Actual No. of Stations})(\text{Max. WS Time})}$$

14.5

9 **3.4**

Task	Preceded by	Time (minutes)
A	-	0.8
B	A	1.3
C	A	3.4
D	-	1.5
E	B	1.8
F	C,D	1.5
G	E	1.0
H	E,F	2.1
I	G,H	1.1

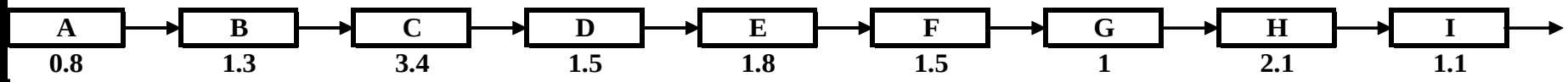
	Total	14.5

For the above production line, the Efficiency will be E = 14.5 / (9 * 3.4) = 0.4739.

Usually E is expressed as a percentage by multiplying the above number by 100 (47.39%).

Considering the above example; is it possible to improve the efficiency of the line for the same cycle time of 3.4 minutes? How?

Yes **Group the tasks better, somehow.**



One way of balancing the assembly line is to group individual tasks into work stations such that the total time in each work station is as close to the cycle time as possible but not more than the cycle time and of course without violating the precedence relationships.

Suppose in the example above that the required production rate is 12 units/hour.

Therefore, the equivalent cycle time is: **5 minutes**

Is this feasible? Yes/No and why ? **Yes** **Max task time (3.4) is less than 5 mins.)**

What is the minimum number of stations (N_{Min}) we can have for this production rate?

$$N_{\text{Min}} = \frac{\sum TaskTime}{CycleTime} = \frac{14.5}{5}$$ **= 2.9 or 3 stations**

In the case that N_{min} is not an integer, it must be rounded UP to the next highest integer (e.g.: suppose the ratio is 5.1, then the minimum number of stations will have to be 6).

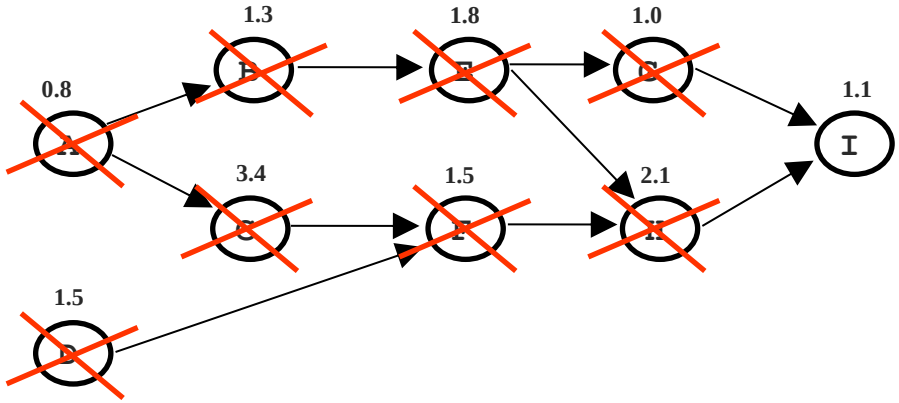
For this illustration, let us now see if we could design a production line that would enable us to have the desired cycle time of 5 minutes (hence the desired production rate of 12 units per hour) with 3 as the minimum number of workstations.

Due to precedence relationships and the individual task times, it might not always be possible to achieve the minimum number of stations (i.e., 3 in this case).

Using Longest Task Time (LTT) Method to assign tasks to Stations

Task	Preceded by	Time (minutes)	LTT Priority
A	-	0.8	9
B	A	1.3	6
C	A	3.4	1
D	-	1.5	4
E	B	1.8	3
F	C,D	1.5	4
G	E	1.0	8
H	E,F	2.1	2
I	G,H	1.1	7
		14.5	

Required Cycle Time = **5** minutes (since required production rate = 12 units/hour)



LTT

A - 0.8
B - 1.3
C - 3.4
D - 1.5
E - 1.8
F - 1.5
G - 1.0
H - 2.1
I - 1.1

WS 1	WS 2	WS 3	WS 4
D: 1.5 / 3.5	C: 3.4 / 1.6	E: 1.8 / 3.2	I: 1.1 / 3.9
A: 0.8 / 2.7	F: 1.5 / 0.1	H: 2.1 / 1.1	
B: 1.3 / 1.4		G: 1.0 / 0.1	
3.6	4.9	4.9	1.1

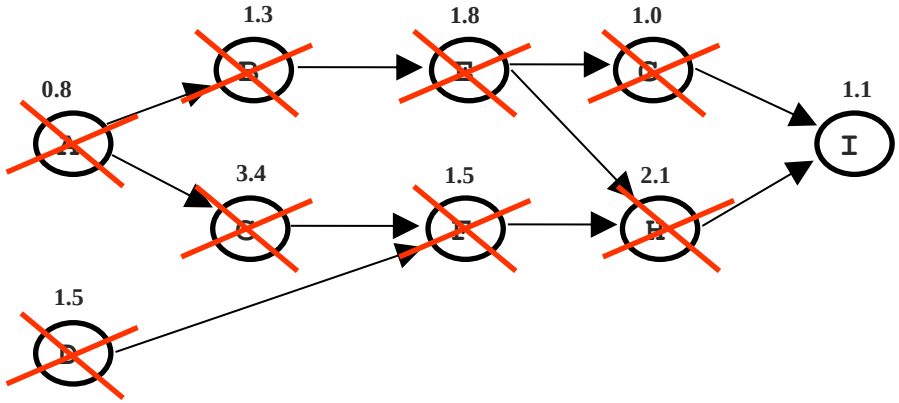
Efficiency: **14.5 / (4 * 4.9) = 73.98%**

Using the Largest Number of Following Tasks (NFT) Method to assign tasks to stations

Task	Preceded by	Time (min.)	NFT	NFT priority
A	-	0.8	7 (specifically tasks B,C,E,F,G,H & I)	1
B	A	1.3	4 (specifically tasks E,G,H & I)	2
C	A	3.4	3	3
D	-	1.5	3	3
E	B	1.8	3	3
F	C,D	1.5	2	6
G	E	1.0	1	7
H	E,F	2.1	1	7
I	G,H	1.1	0	9

Cycle Time = 5 Minutes.

Required Cycle Time = **5** minutes (since required production rate = 12 units/hour)



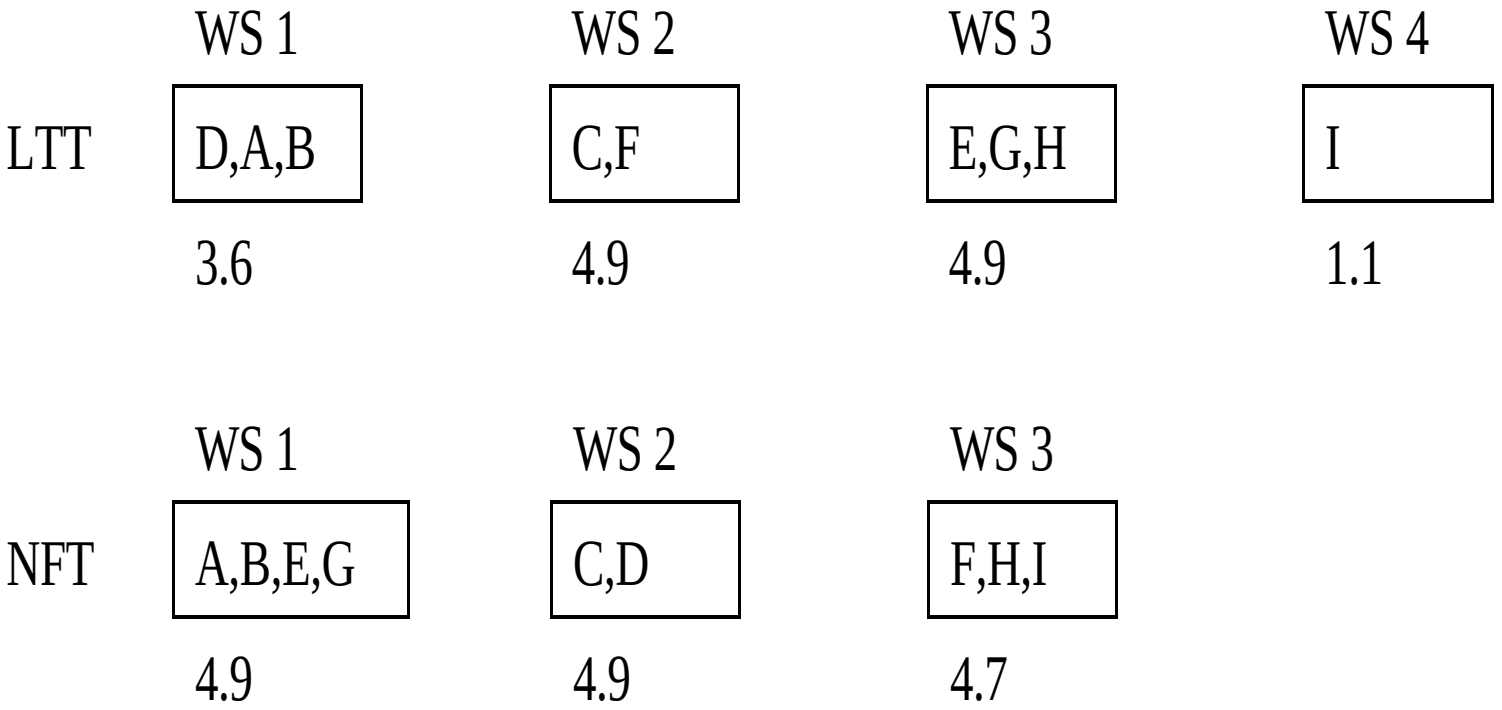
NFT / LTT

1 A - 0.8
2 B - 1.3
3 C - 3.4
3 D - 1.5
3 E - 1.8
6 F - 1.5
7 G - 1.0
7 H - 2.1
9 I - 1.1

WS 1	WS 2	WS 3	WS 4
A: 0.8 / 4.2	C: 3.4 / 1.6	F: 1.5 / 3.5	
B: 1.3 / 2.9	D: 1.5 / 0.1	H: 2.1 / 1.4	
E: 1.8 / 1.1	4.9	I: 1.1 / 0.3	
G: 1.0 / 0.1		4.7	
4.9			

Efficiency: **14.5 / (3 * 4.9) = 98.64%**

Assembly Line Layouts Produced by the two methods:



How do I choose product or process layout?

- Market conditions and competition
- Capital requirements
- Labor supply and cost
- Management skills
- Materials supply and cost
- State of technology

Summary

- What is facility layout?
- What is the difference between process versus product layout?
  - ✓ Where is each best?
- What are the 7 layout strategies
- What is a layout strategy for a retail facility?