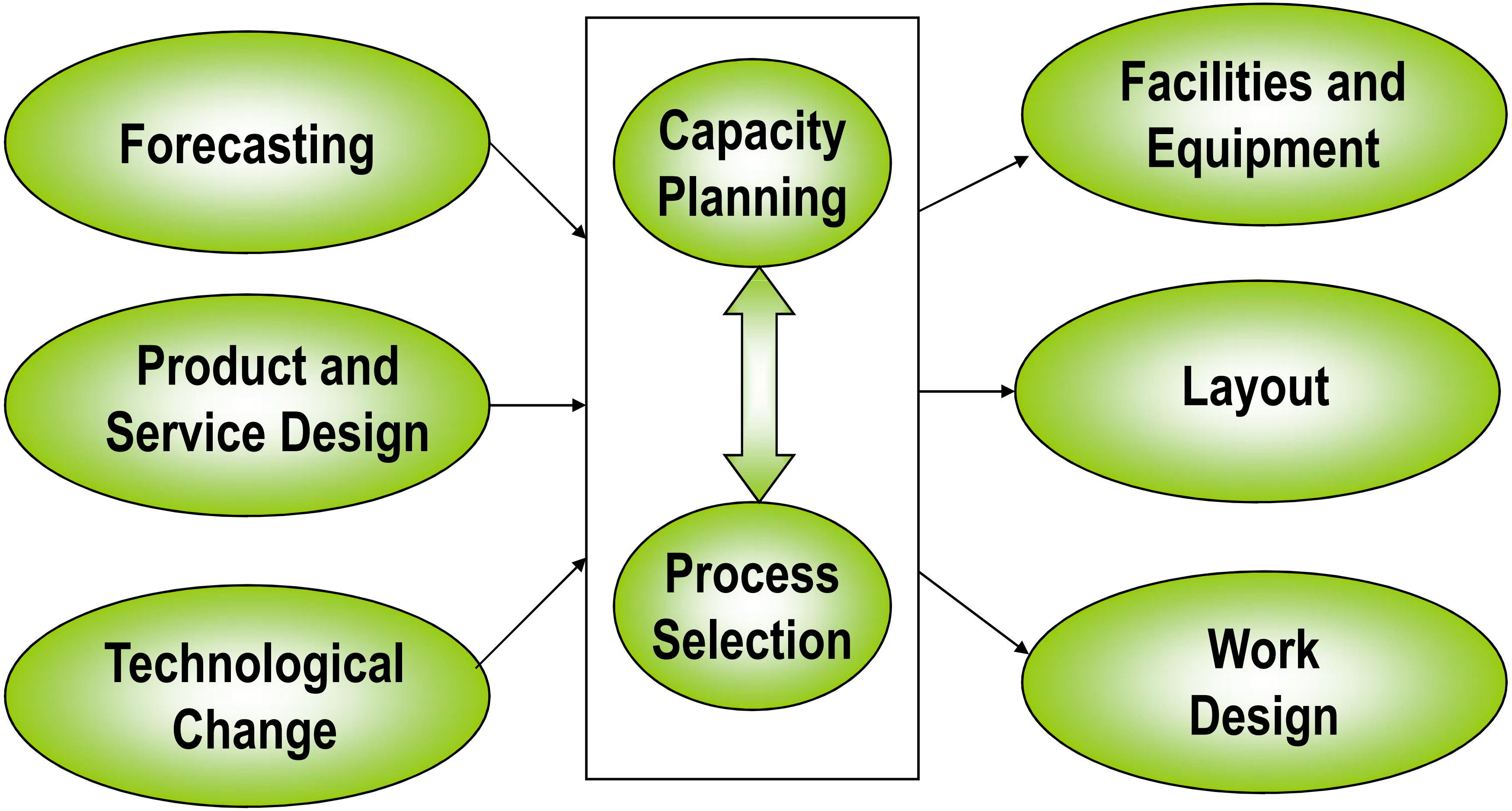
CHAPTER 6

Process Selection and Facility Layout

22/01/2012

Process Selection and System Design.



Forecasting

Product and Service Design

Technological Change

Capacity Planning

Process Selection

Facilities and Equipment

Layout

Work Design

Process Selection

- Variety

  How much variety in products or service will the system need to handle ?

- Flexibility

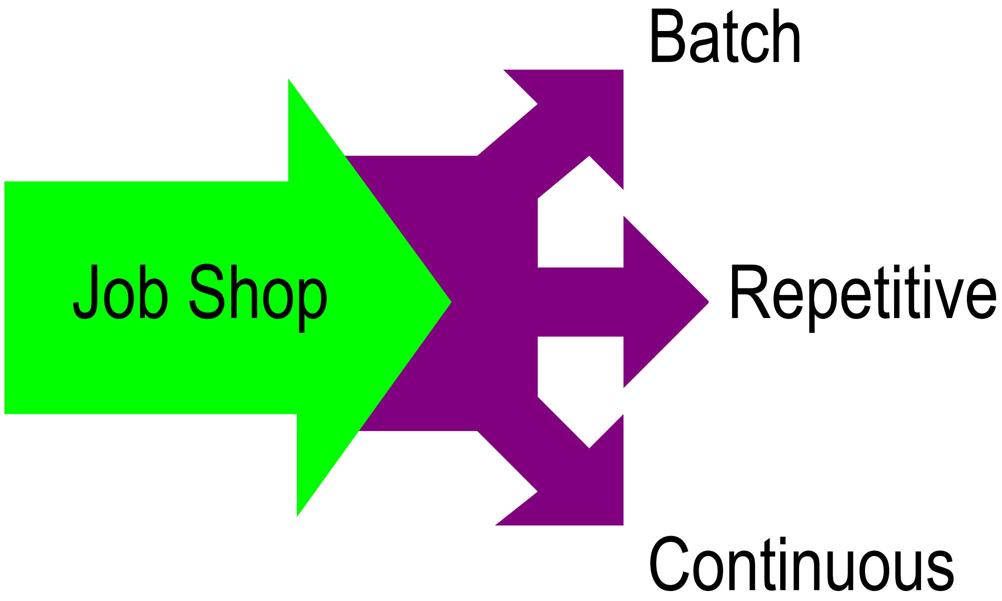
  What degree of equipment flexibility will be needed ?

- Volume

  What is the expected volume of output ?

Process Types

- Job shop
  - Small scale
- Batch
  - Moderate volume
- Repetitive/assembly line
  - High volumes of standardized goods or services
- Continuous
  - Very high volumes of non-discrete goods



Product and Service Processes

Process Type	Low Volume	→		High Volume
Job Shop	Appliance repair Emergency room			Ineffective
Batch		Commercial baking Classroom Lecture		
Repetitive			Automotive assembly Automatic carwash	
Continuous (flow)	Ineffective			Steel Production Water purification

Product – Process Matrix

Dimension	Job shop	Batch	Repetitive	Continuous
Job variety	Very High	Moderate	Low	Very low
Process flexibility	Very High	Moderate	Low	Very low
Unit cost	Very High	Moderate	Low	Very low
Volume of output	Very low	Low	High	Very High

Other issues; scheduling

work-in-process inventory

labor skill

Process and Product Profiling

- Process selection can involve substantial investment in
  - Equipment
  - Layout of facilities
- **Product profiling**: Linking key product or service requirements to process capabilities
- Key dimensions
  - Range of products or services
  - Expected order sizes
  - Pricing strategies
  - Expected schedule changes
  - Order winning requirements

Automation

- *Automation*: Machinery that has sensing and control devices that enables it to operate
  - Fixed automation
  - Programmable automation

Automation (cont.)

- Computer-aided design and manufacturing systems (CAD/CAM)
- Numerically controlled (NC) machines
- Robot
- Manufacturing cell
- Flexible manufacturing systems (FMS)
- Computer-integrated manufacturing (CIM)

Facilities Layout

- *Layout*: the configuration of departments, work centers, and equipment, with particular emphasis on movement of work (customers or materials) through the system
    - Product layouts
    - Process layouts
    - Fixed-Position layout
    - Combination layouts

Objective of Layout Design

- Facilitate attainment of product quality
- Use workers and space efficiently
- Avoid bottlenecks
- Minimize unnecessary material handling costs
- Eliminate unnecessary movement of workers or materials
- Minimize production time or customer service time
- Design for safety

Basic Layout Types

- Fixed-Position layout
- Product layouts
- Process layouts
- Cellular Layouts
- Service layouts
  - Office layout
  - Retail layout
  - Warehouse layout

Fixed Position Layouts

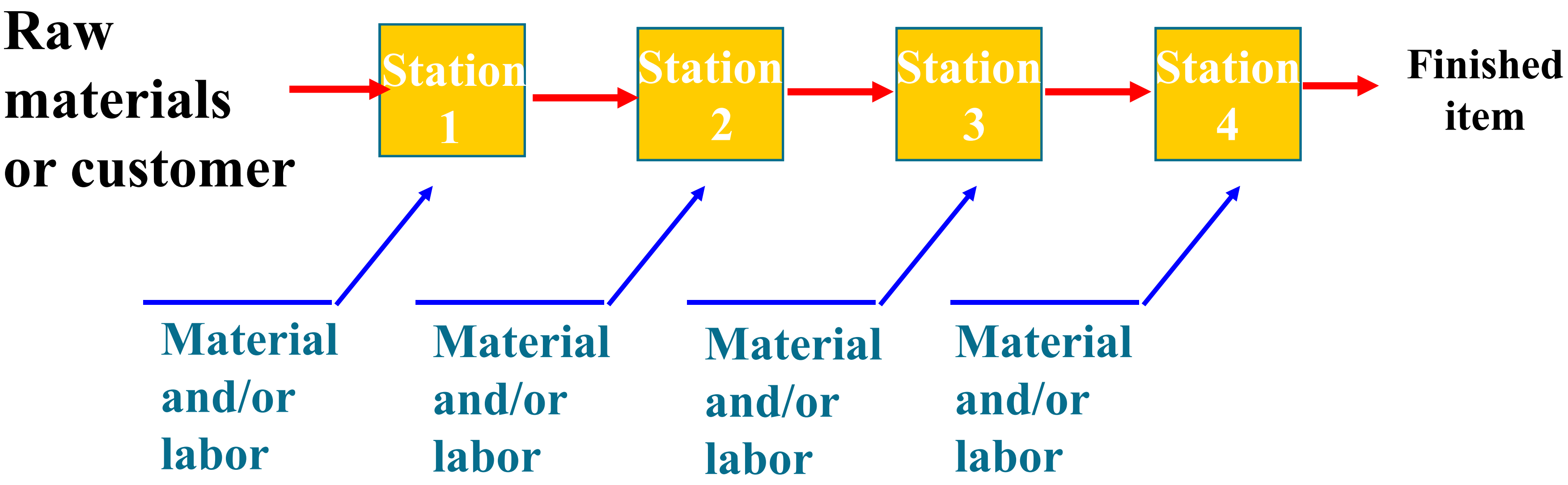
- Fixed Position Layout: Layout in which the product or project remains stationary, and workers, materials, and equipment are moved as needed.
- Nature of the product dictates this type of layout
  - Weight
  - Size
  - Bulk
- Large construction projects

Fixed Position Layouts (cont.)

- Typical of projects
- Equipment, workers, materials, other resources brought to the site
- Highly skilled labor
- Often low fixed costs
- Typically high variable costs

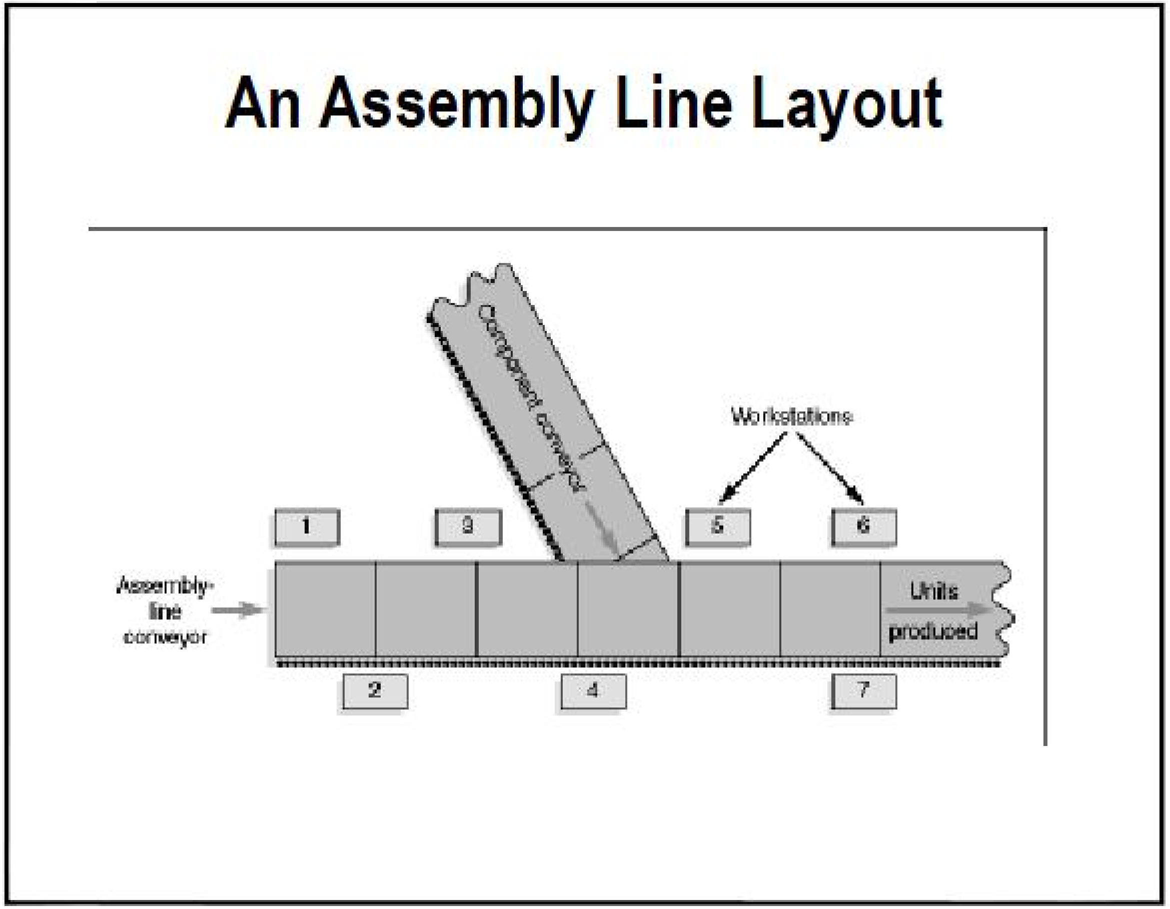
Product Layout

Used for Repetitive or Continuous Processing



Product Layout (cont.)

Flow shop production (Product-oriented layout): seeks the best personnel and machine utilization in repetitive or continuous production.



Advantages of Product Layout

- High rate of output
- Low unit cost
- Labor specialization
- Low material handling cost
- High utilization of labor and equipment
- Established routing and scheduling
- Routine accounting, purchasing and inventory control

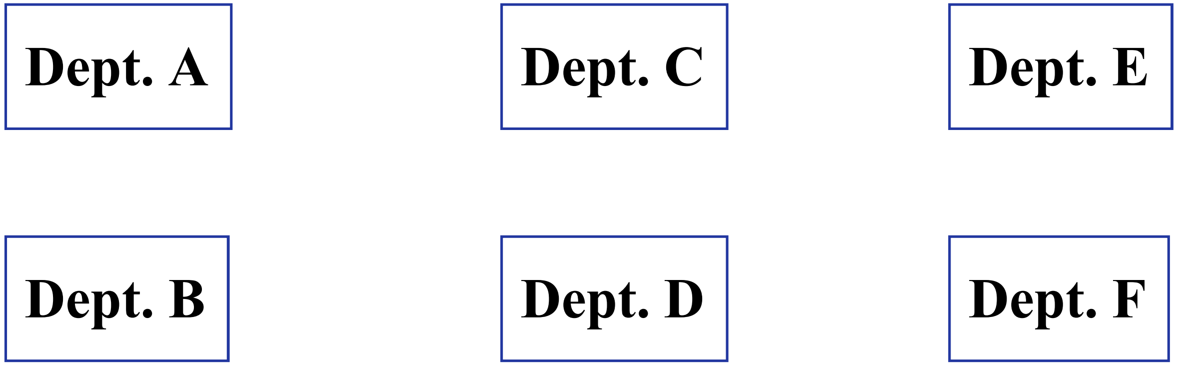
Disadvantages of Product Layout

- Creates dull, repetitive jobs
- Poorly skilled workers may not maintain equipment or quality of output
- Fairly inflexible to changes in volume
- Highly susceptible to shutdowns
- Needs preventive maintenance
- Individual incentive plans are impractical

Process Layout

Process Layout

(functional)



Dept. A

Dept. C

Dept. E

Dept. B

Dept. D

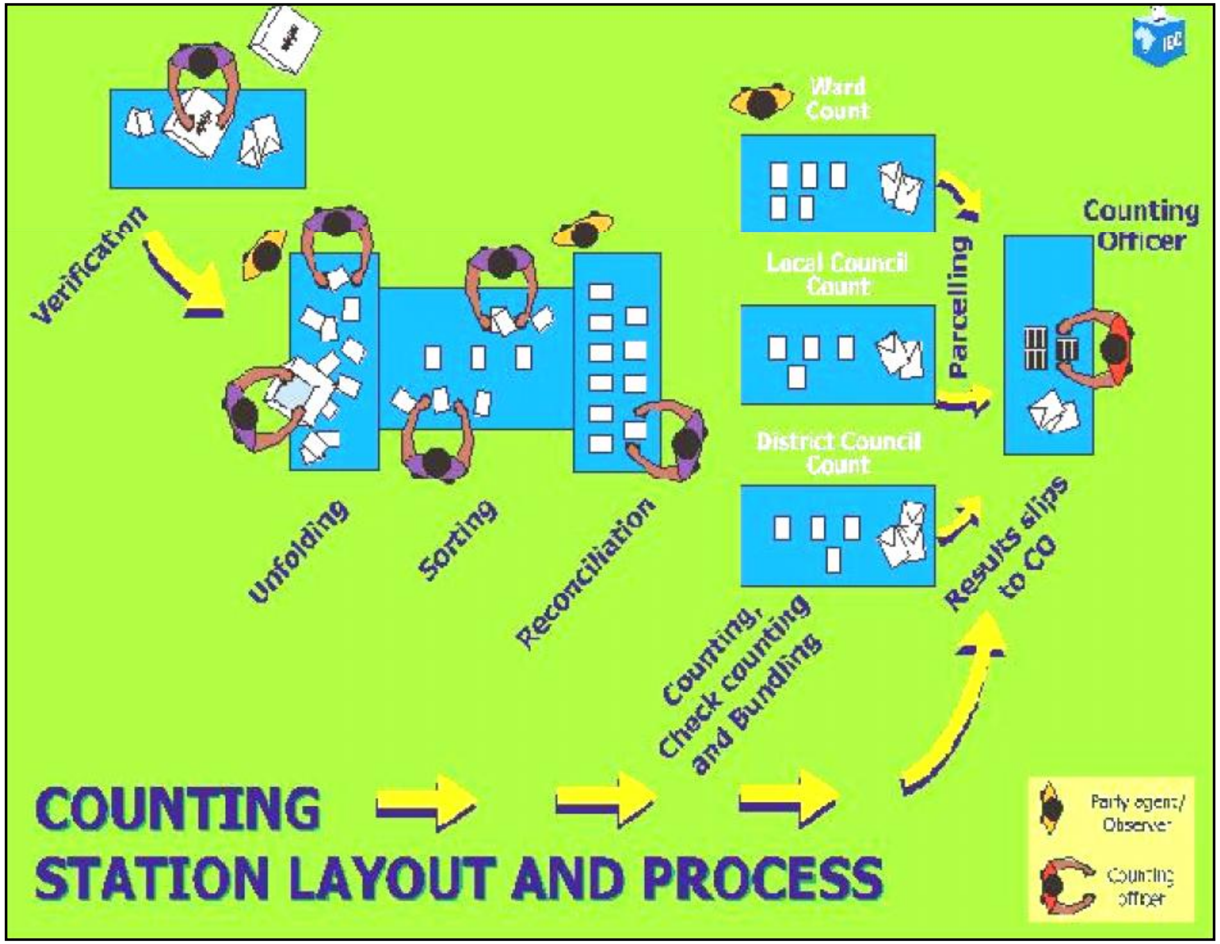
Dept. F

Used for Intermittent processing

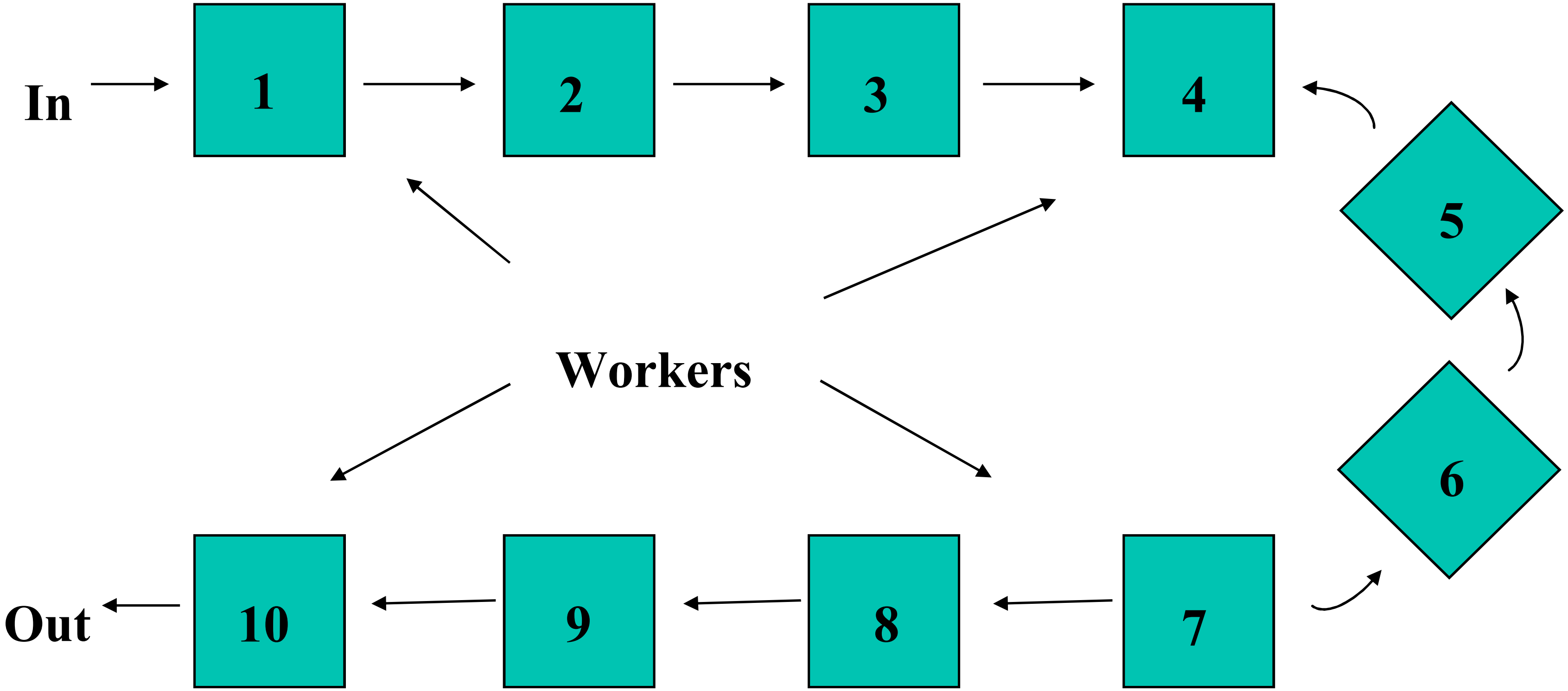
Job Shop or Batch Processes

Process Layout (cont.)

Job shop production (Process-oriented layout): deals with low-volume, high-variety production



A U-Shaped Production Line



- Ease to cross-travel of workers and vehicles
- More compact
- More communication between workers

Advantages of Process Layouts

- Can handle a variety of processing requirements
- Not particularly vulnerable to equipment failures
- Equipment used is less costly
- Possible to use individual incentive plans

Disadvantages of Process Layouts

- In-process inventory costs can be high
- Challenging routing and scheduling
- Equipment utilization rates are low
- Material handling slow and inefficient
- Complexities often reduce span of supervision
- Special attention for each product or customer
- Accounting and purchasing are more involved

Process-oriented layout

- Design places departments with large flows of material or people together
- Department areas having similar processes located in close proximity

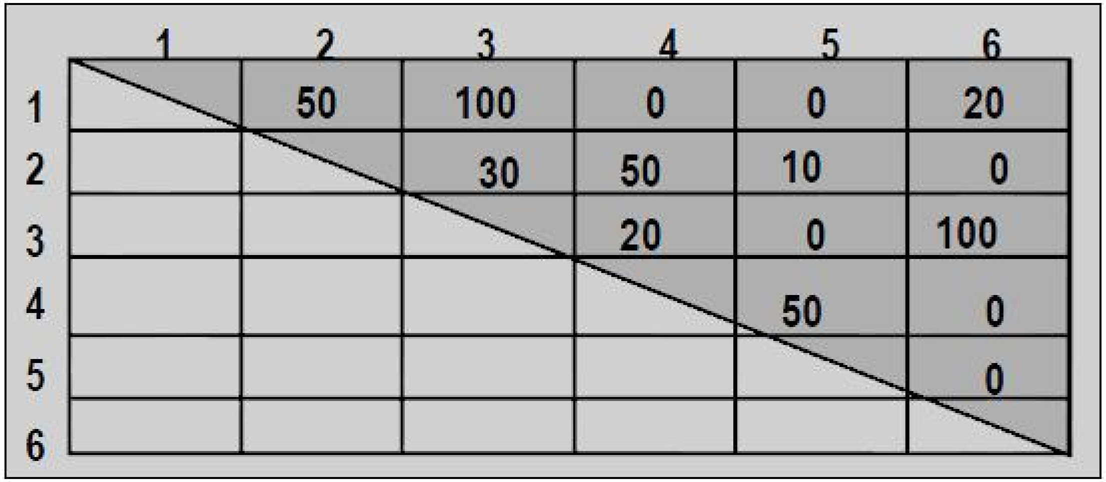
Process-oriented layout (cont.)

- Steps in Developing a Process-Oriented Layout

1. Construct a “from-to matrix”

station

station

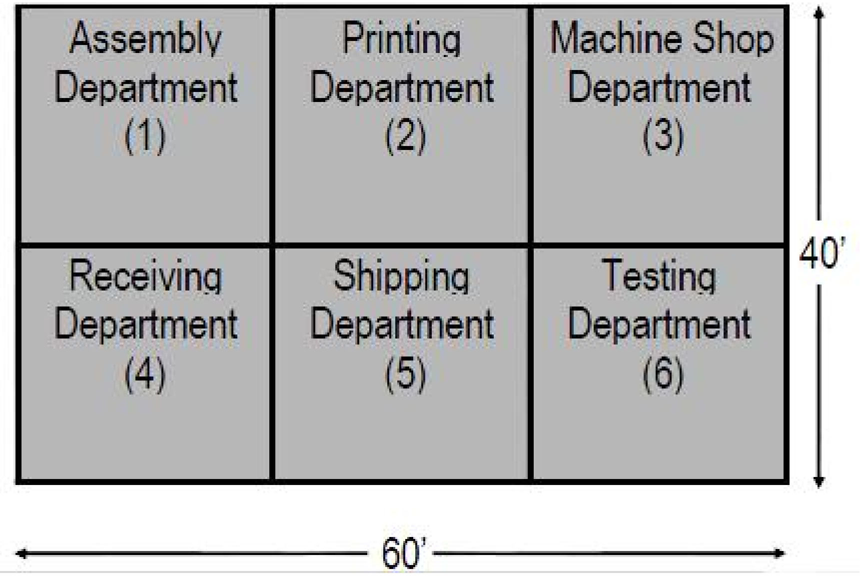


	1	2	3	4	5	6
1		50	100	0	0	20
2			30	50	10	0
3				20	0	100
4					50	0
5						0
6						

Process-oriented layout (cont.)

- Steps in Developing a Process-Oriented Layout

  2.Determine space requirements for each department

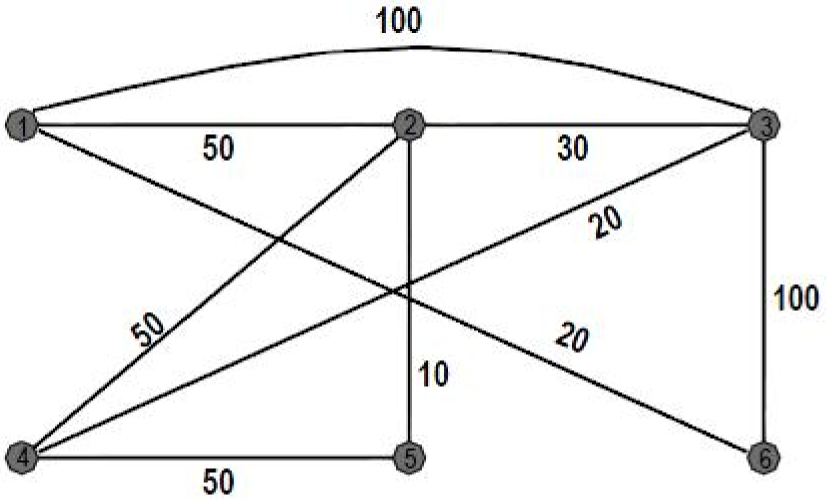


Assembly Department (1)	Printing Department (2)	Machine Shop Department (3)
Receiving Department (4)	Shipping Department (5)	Testing Department (6)

Process-oriented layout (cont.)

- Steps in Developing a Process-Oriented Layout

  3. Develop an initial schematic diagram



Process-oriented layout (cont.)

- Steps in Developing a Process-Oriented Layout

  Cost of Process-Oriented Layout

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

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

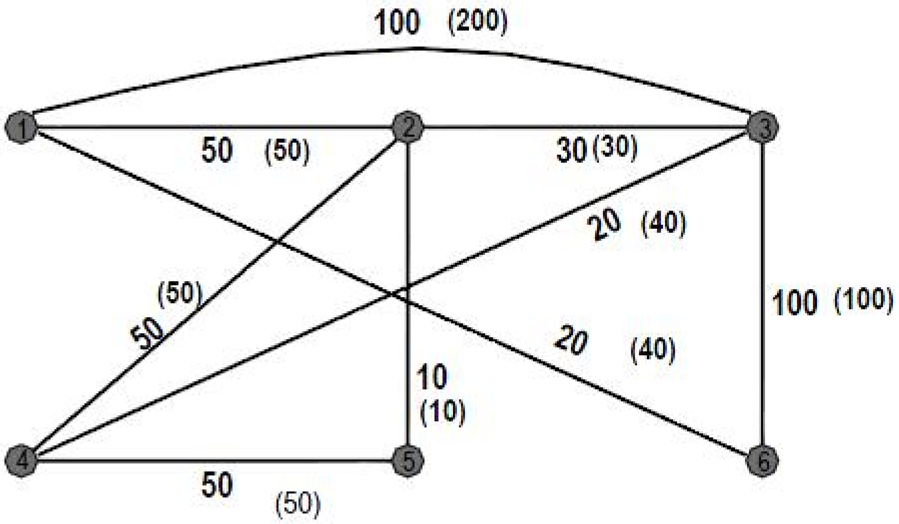
Process-oriented layout (cont.)

- Steps in Developing a Process-Oriented Layout

  4. Determine the cost of the layout

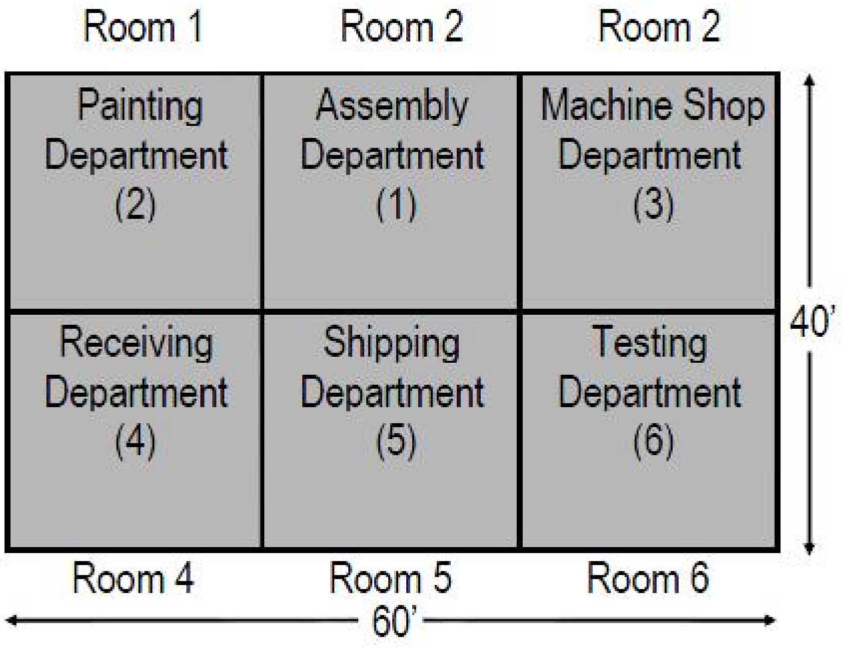
Cost of moving 1 unit between adjacent departments is 1 dollar

Cost of moving 1 unit between nonadjacent departments is 2 dollar



Process-oriented layout (cont.)

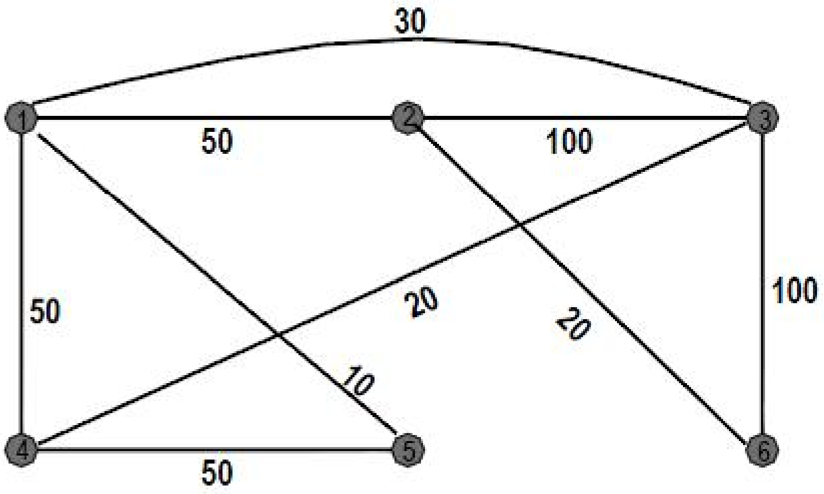
- Possible Layout 2



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

Process-oriented layout (cont.)

- Interdepartmental Flow Graph Showing Number of Weekly Loads



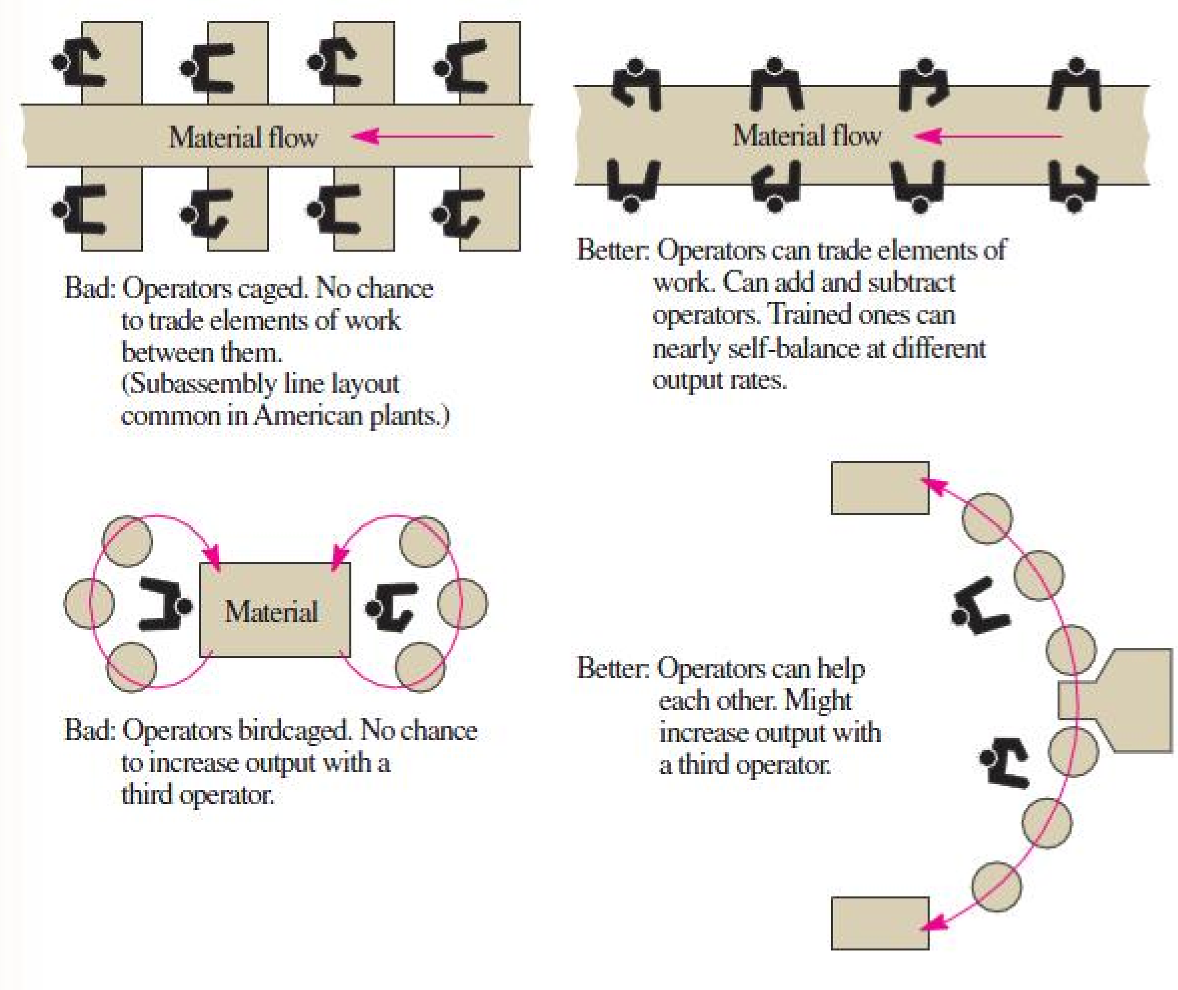
Cellular Layouts

Cellular manufacturing systems (work cell layout): arranges machinery and equipment to focus on production of a single product or group of related products

- Cellular Production
  - Layout in which machines are grouped into a cell that can process items that have similar processing requirements
- Group Technology
  - The grouping into part families of items with similar design or manufacturing characteristics

Cellular Layouts (cont.)

- Work Cells



Bad: Operators caged. No chance to trade elements of work between them. (Subassembly line layout common in American plants.)

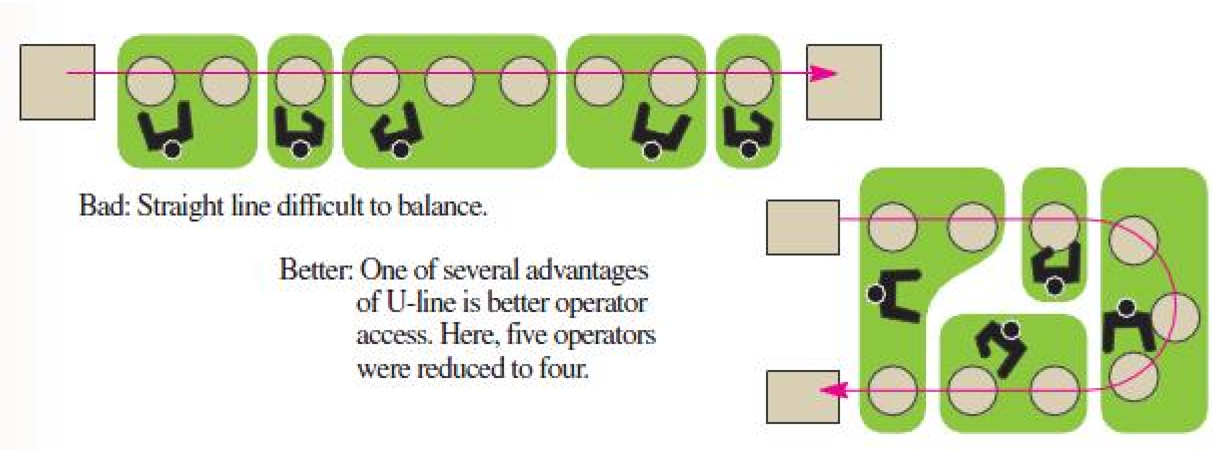
Better: Operators can trade elements of work. Can add and subtract operators. Trained ones can nearly self-balance at different output rates.

Bad: Operators birdcaged. No chance to increase output with a third operator.

Better: Operators can help each other. Might increase output with a third operator.

Cellular Layouts (cont.)

- Work Cells



Bad: Straight line difficult to balance.

Better: One of several advantages of U-line is better operator access. Here, five operators were reduced to four.

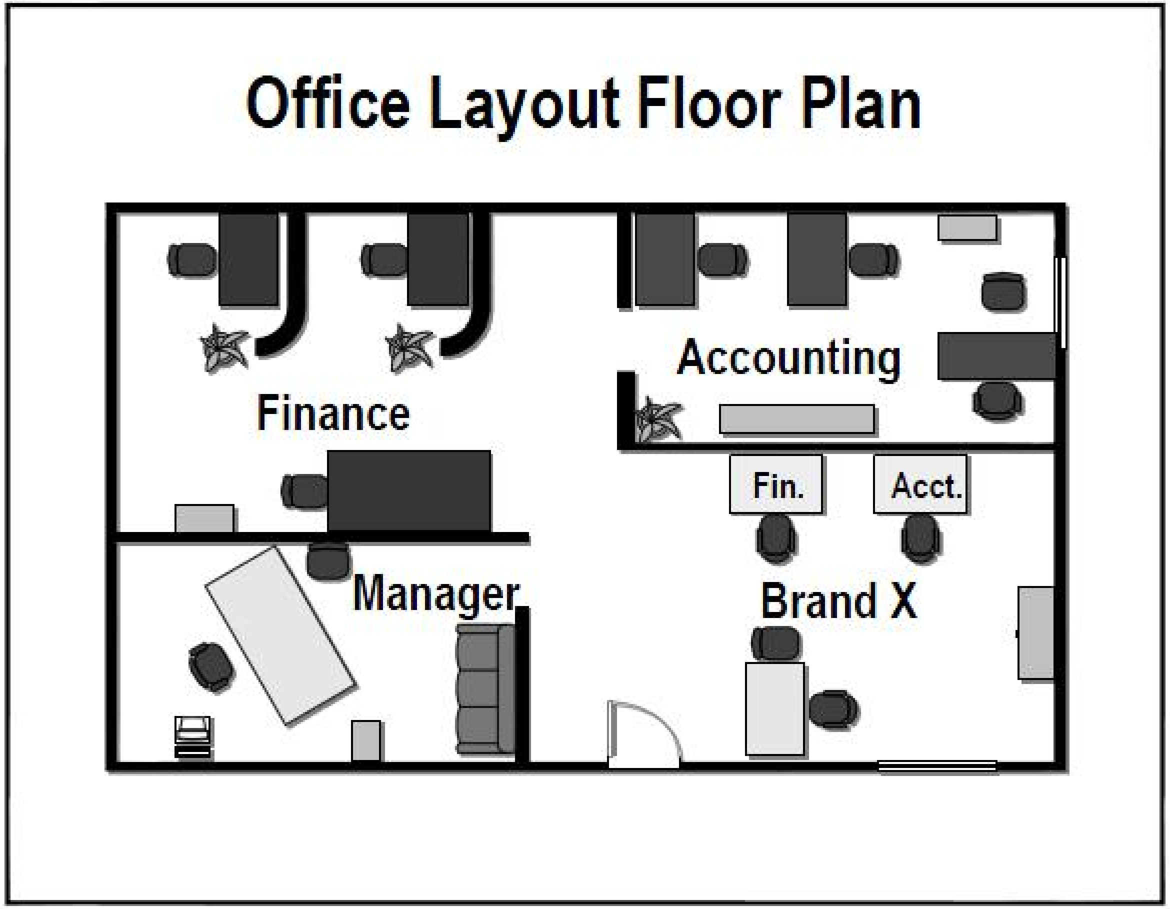
Advantages and Disadvantages of Cellular Layouts

- **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**
  - Expanded training and scheduling of workers
  - Increased capital investment

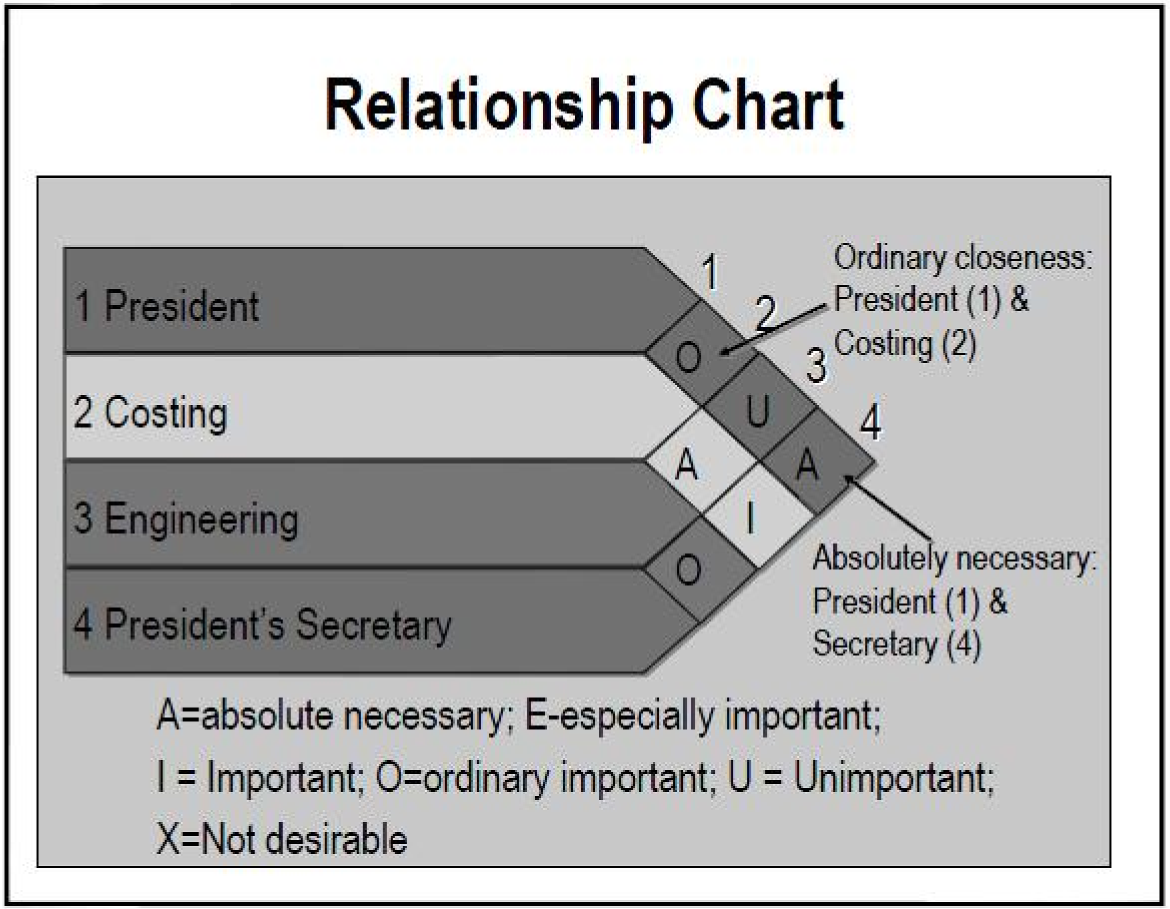
Service Layouts

- ☐ Office layouts
- ☐ Retail layouts
- ☐ Warehouse and storage layouts



Service Layouts (cont.)

- Office Layouts

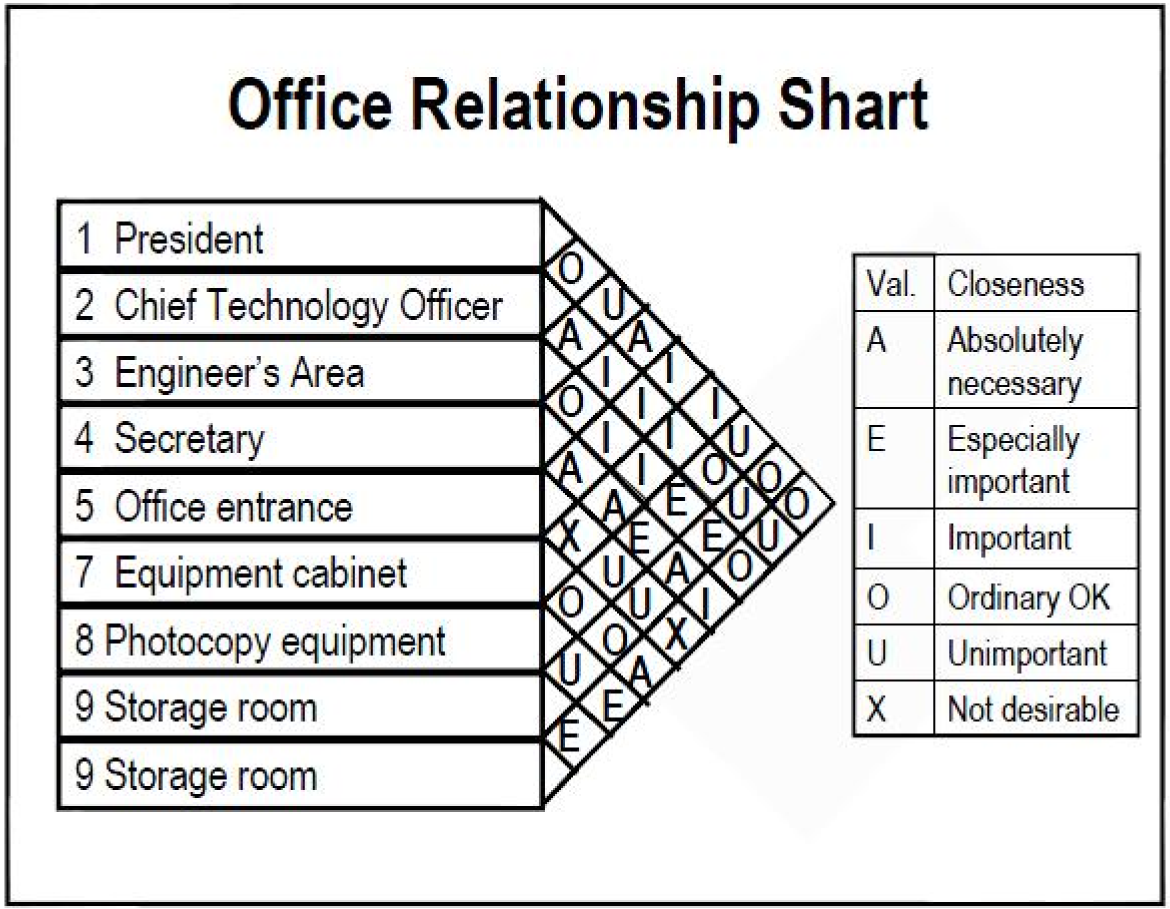


A=absolute necessary; E-especially important;

I = Important; O=ordinary important; U = Unimportant;

X=Not desirable

Office layouts



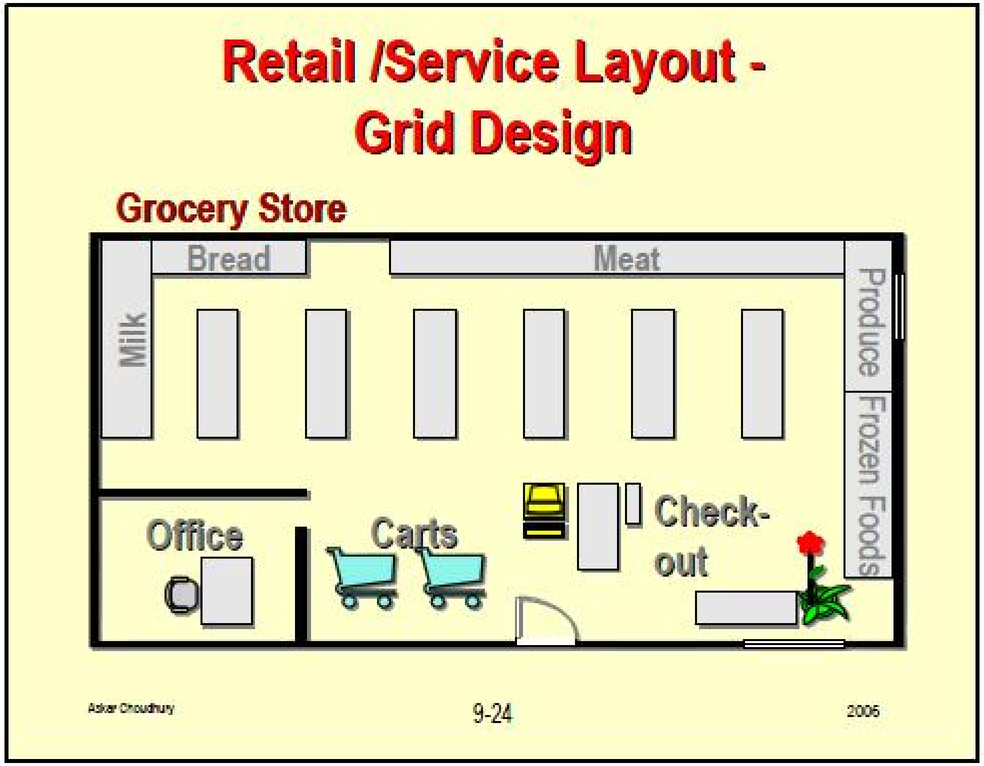
Office Relationship Shart

1 President
2 Chief Technology Officer
3 Engineer's Area
4 Secretary
5 Office entrance
7 Equipment cabinet
8 Photocopy equipment
9 Storage room
9 Storage room

Val.	Closeness
A	Absolutely necessary
E	Especially important
I	Important
O	Ordinary OK
U	Unimportant
X	Not desirable

Service Layouts (cont.)

- Retail layouts
  - Design maximizes product exposure to customers
  - Decision variable
    - Store flow pattern
    - Allocation of (shelf) space to products



Retail /Service Layout - Grid Design

Askar Choudhury

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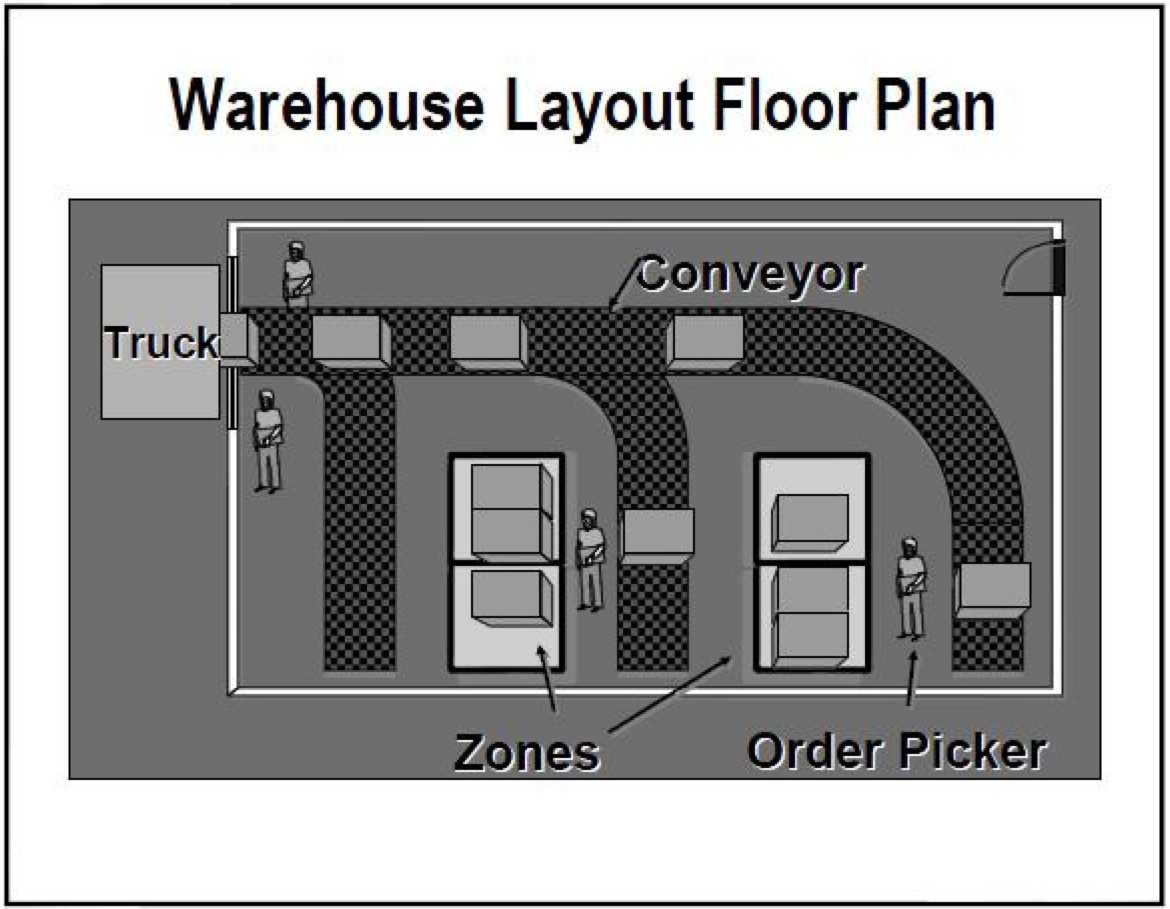
Service Layouts (cont.)

- Warehouse and storage layouts



Design Product Layouts: Line Balancing

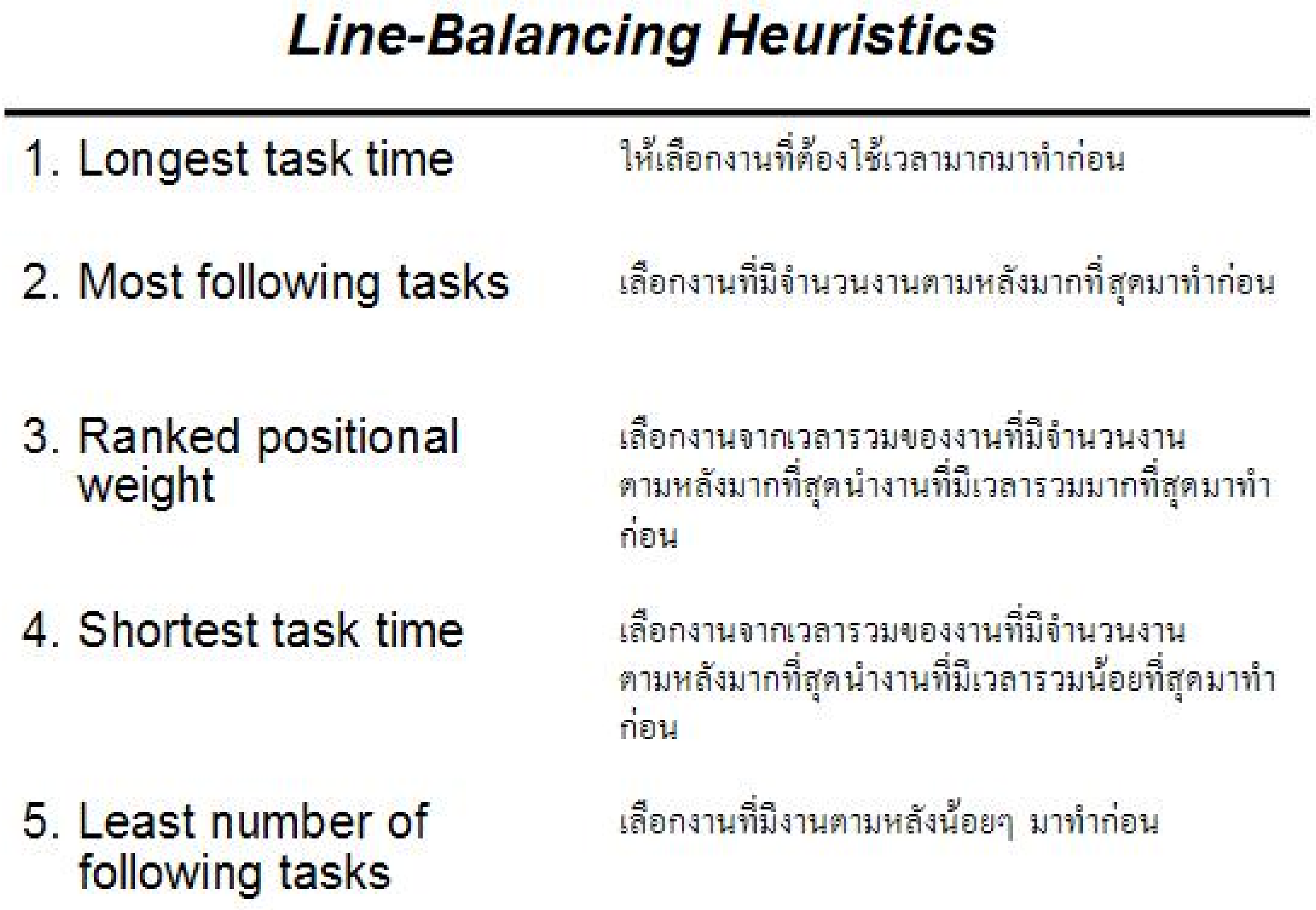
Line Balancing is the process of assigning tasks to workstations in such a way that the workstations have approximately equal time requirements.

Line Balancing Rules

Some Heuristic (intuitive) Rules:

- Assign tasks in order of most following tasks.
  - Count the number of tasks that follow
- Assign tasks in order of greatest positional weight.
  - Positional weight is the sum of each task's time and the times of all following tasks.

Line Balancing Rules (cont.)



Line-Balancing Heuristics

1. Longest task time	ให้เลือกงานที่ต้องใช้เวลามากมาทำก่อน
2. Most following tasks	เลือกงานที่มีจำนวนงานตามหลังมากที่สุดมาทำก่อน
3. Ranked positional weight	เลือกงานจากเวลารวมของงานที่มีจำนวนงานตามหลังมากที่สุดนำงานที่มีเวลารวมมากที่สุดมาทำก่อน
4. Shortest task time	เลือกงานจากเวลารวมของงานที่มีจำนวนงานตามหลังมากที่สุดนำงานที่มีเวลารวมน้อยที่สุดมาทำก่อน
5. Least number of following tasks	เลือกงานที่มีงานตามหลังน้อยๆ มาทำก่อน

Cycle Time

Cycle time is the maximum time allowed at each workstation to complete its set of tasks on a unit.

Determine Maximum Output

$$\text{Output rate} = \frac{OT}{CT}$$

$$CT = \text{cycle time} = \frac{OT}{D}$$

Where OT = Operating time per day

D = Desired output rate

Determine the Minimum Number of Workstations Required

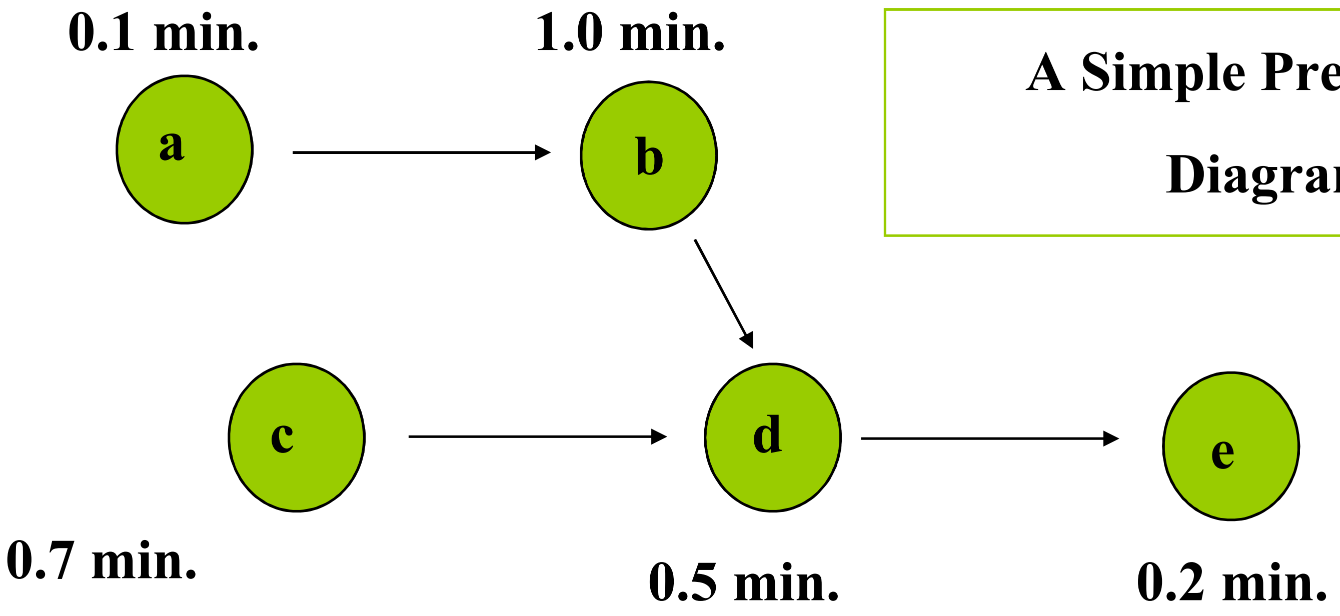
$$N = \frac{(\sum t)}{CT}$$

Where $\sum t = \text{sum of task time}$

N = Minimum number of work station

Precedence Diagram

Precedence diagram: Tool used in line balancing to display elemental tasks and sequence requirements



A Simple Precedence Diagram

Calculate Percent Idle Time

$$\text{Percent idle time} = \frac{\text{Idle time per cycle}}{(N)(CT)}$$

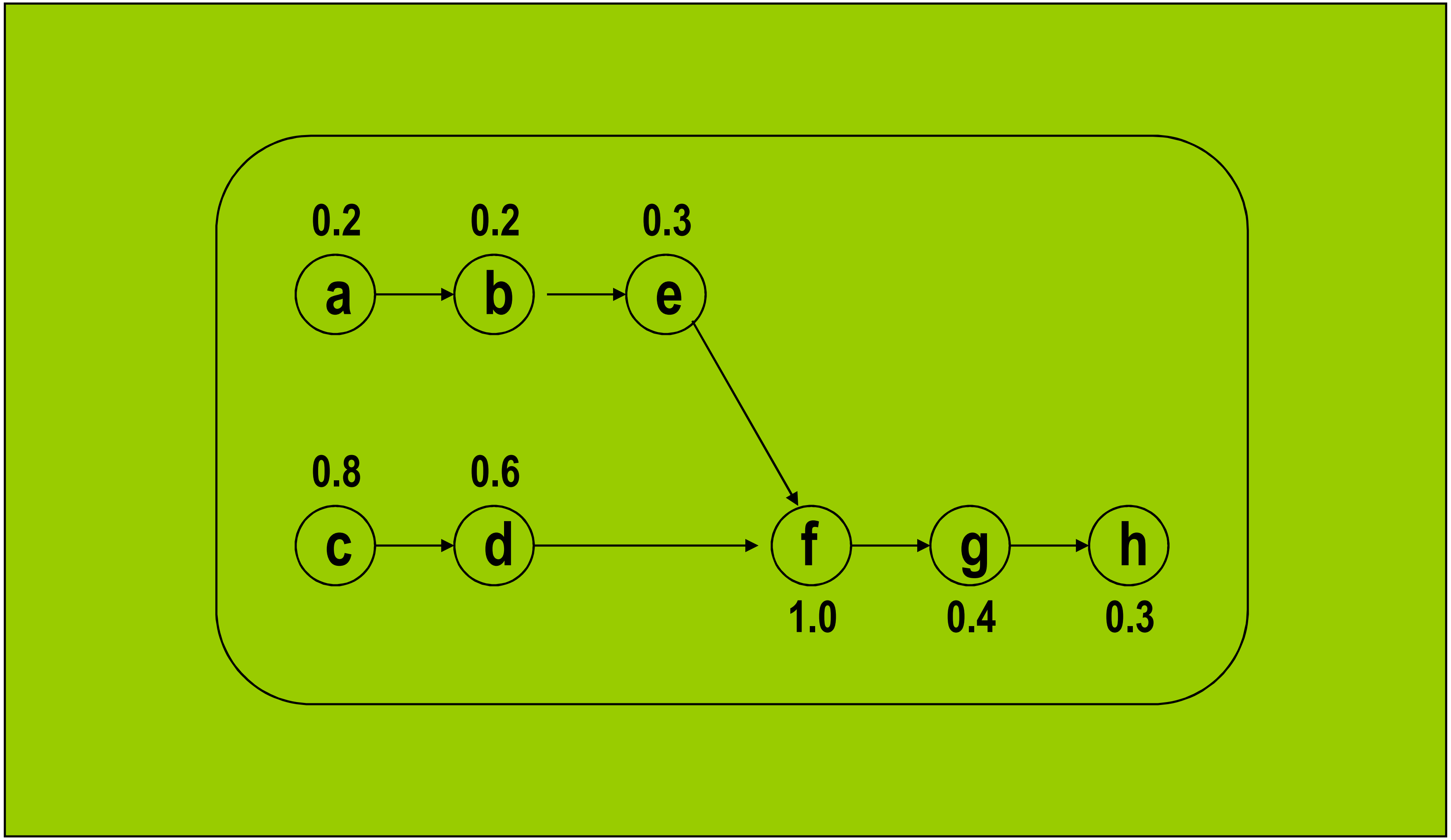
Efficiency = 100 – Percent idle time

Example 1

Plan to produce 400 units in 1 day (8 hours)

Task	Immediate follower	Task time (min)
a	b	0.2
b	e	0.2
c	d	0.8
d	f	0.6
e	f	0.3
f	g	1.0
g	h	0.4
h	end	0.3

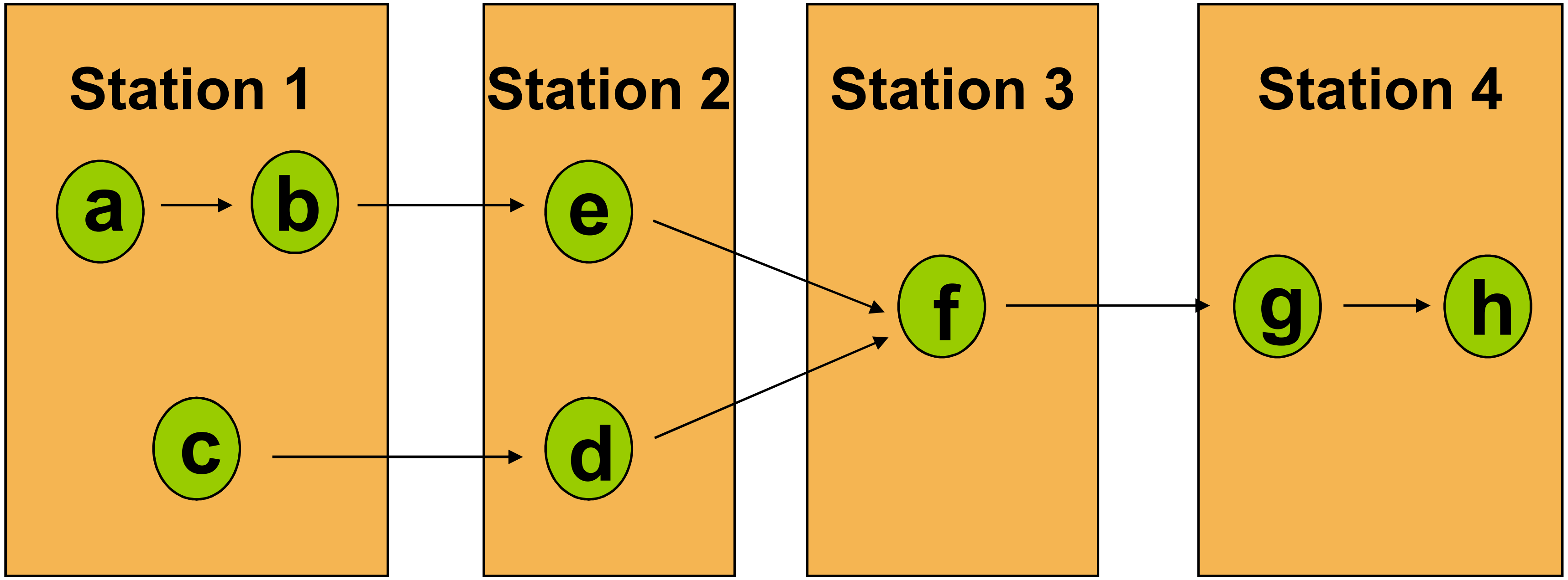
Solution to Example 1 (cont.)



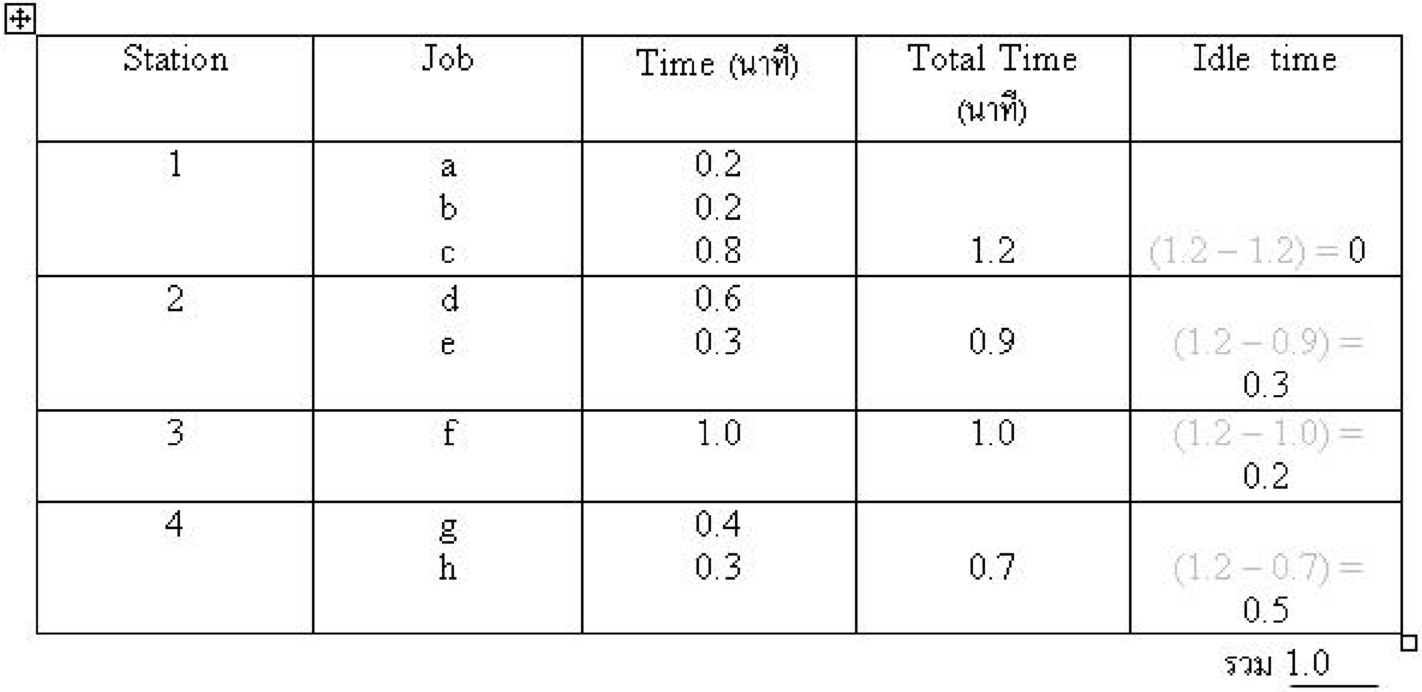
Solution to Example 1 (cont.)

$$CT = \text{cycle time} = \frac{480}{400} = 1.2 \text{ min}$$

$$N = \frac{3.8}{1.2} = 4$$



Solution to Example 1 (cont.)



Station	Job	Time (นาที)	Total Time (นาที)	Idle time
1	a b c	0.2 0.2 0.8	1.2	(1.2 – 1.2) = 0
2	d e	0.6 0.3	0.9	(1.2 – 0.9) = 0.3
3	f	1.0	1.0	(1.2 – 1.0) = 0.2
4	g h	0.4 0.3	0.7	(1.2 – 0.7) = 0.5

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Solution to Example 1 (cont.)

$$\text{Percent idle time} = \frac{\text{Idle time per cycle}}{(N)\ (CT)}$$

$$= \frac{1}{4x1.2}$$

$$= 20.8\%$$

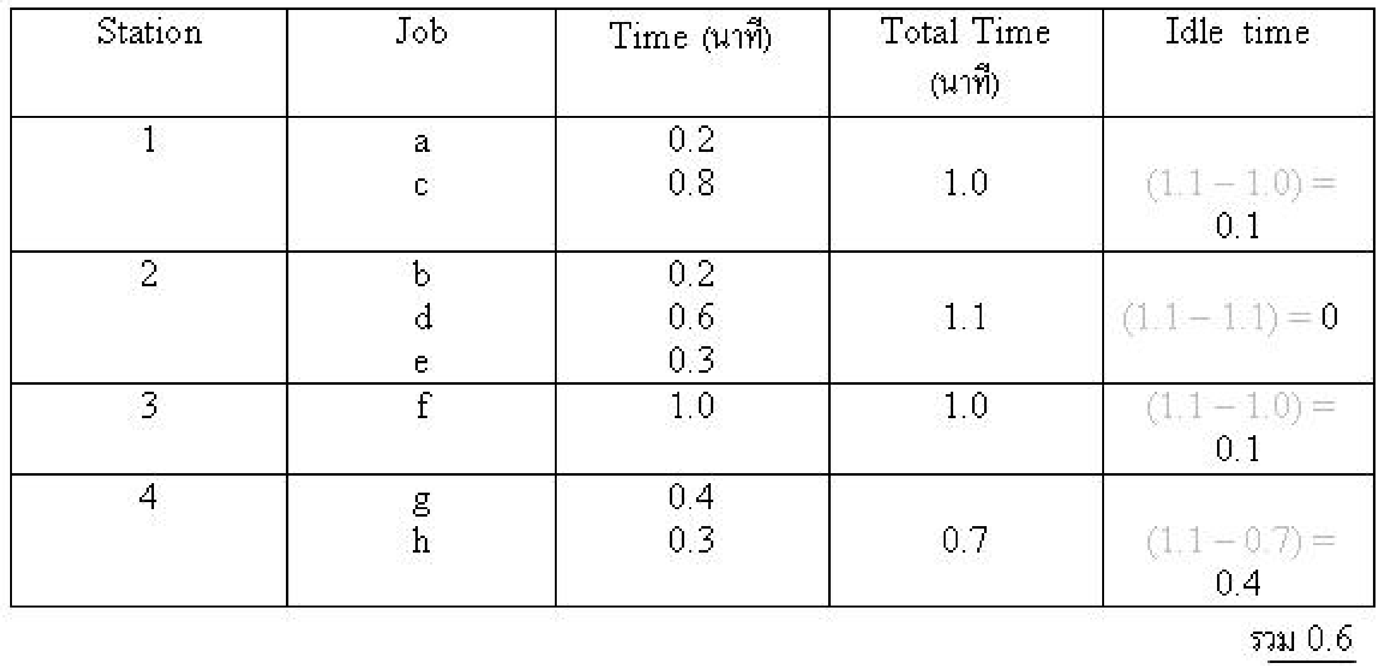
Efficiency = 100 – Percent idle time

= 100- 20.8

= 72.9 %

Solution to Example 1 (cont.)

Move b from station 1 to station 2



Station	Job	Time (นาที)	Total Time (นาที)	Idle time
1	a c	0.2 0.8	1.0	(1.1 – 1.0) = 0.1
2	b d e	0.2 0.6 0.3	1.1	(1.1 – 1.1) = 0
3	f	1.0	1.0	(1.1 – 1.0) = 0.1
4	g h	0.4 0.3	0.7	(1.1 – 0.7) = 0.4

รวม 0.6

Solution to Example 1 (cont.)

$$\text{Percent idle time} = \frac{\text{Idle time per cycle}}{(N)\,(CT)}$$

$$= \frac{0.6}{4\text{x}1.1}$$

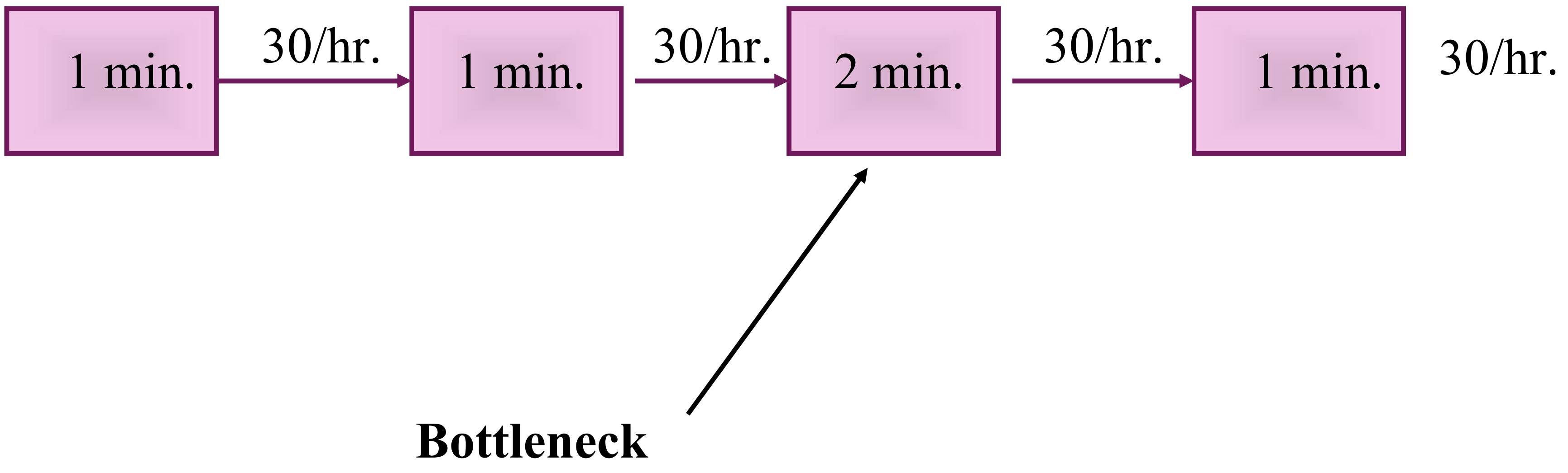
$$= 13.6\%$$

$$\text{Efficiency} = 100 - \text{Percent idle time}$$

$$= 100 - 13.6$$

$$= 86.4\ \%$$

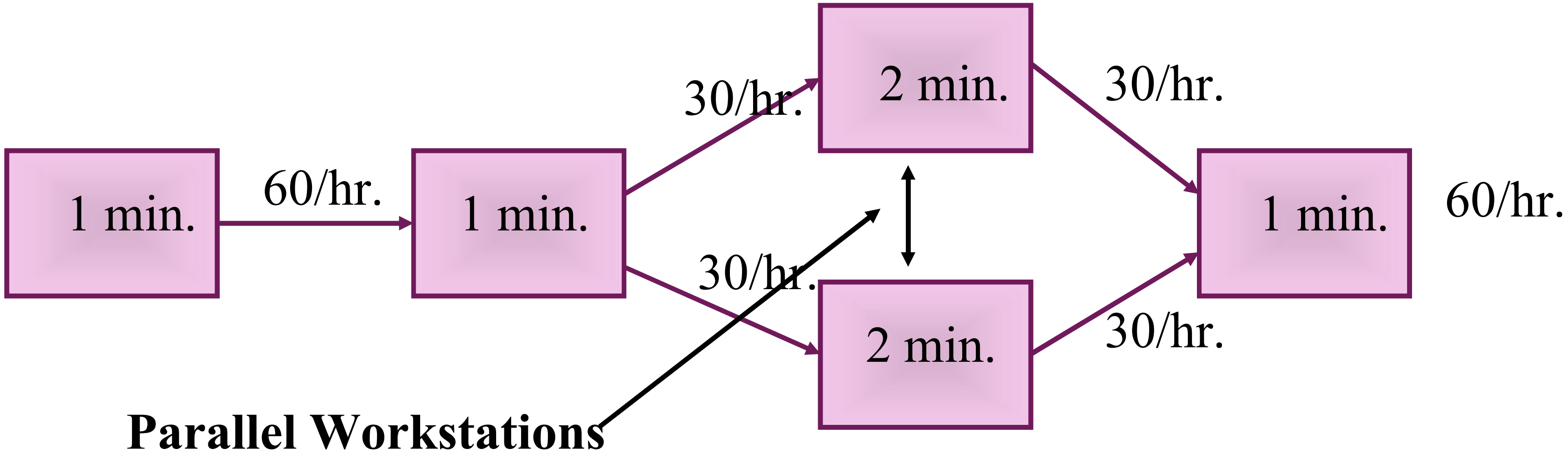
Bottleneck Workstation



1 min. → 30/hr. → 1 min. → 30/hr. → 2 min. → 30/hr. → 1 min. 30/hr.

Bottleneck

Parallel Workstations



Example TN5.2

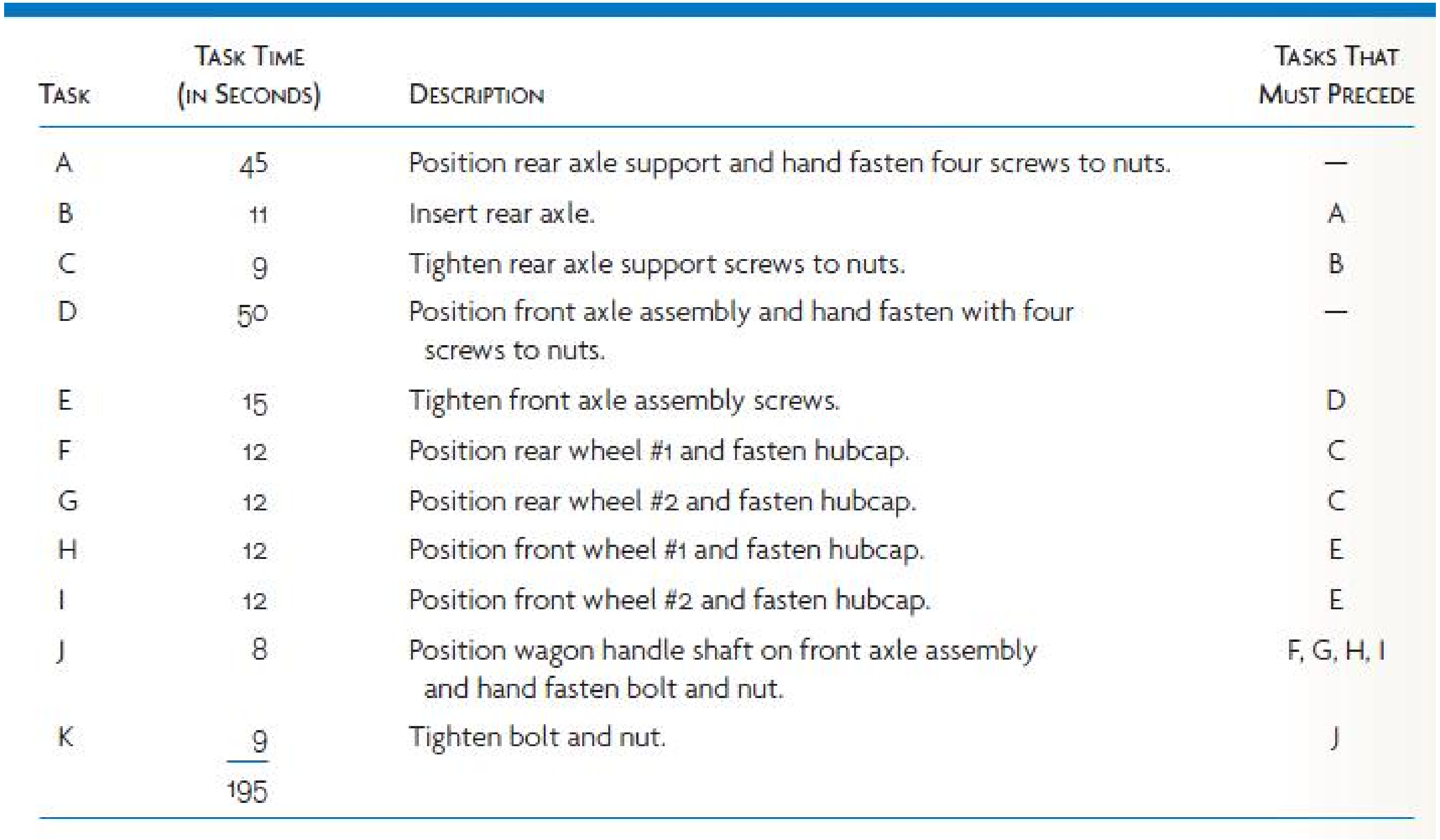
Assembly-Line Balancing

The Model J Wagon is to be assembled on a conveyor belt. 500 wagons are required per day. Production time per day is 420 minutes, and the assembly steps and times for the wagon are give in Exhibit TN5.10 Assignment: Find the balance that minimizes the number of workstations, subject to Cycle time and precedence constraints.

SOLUTION

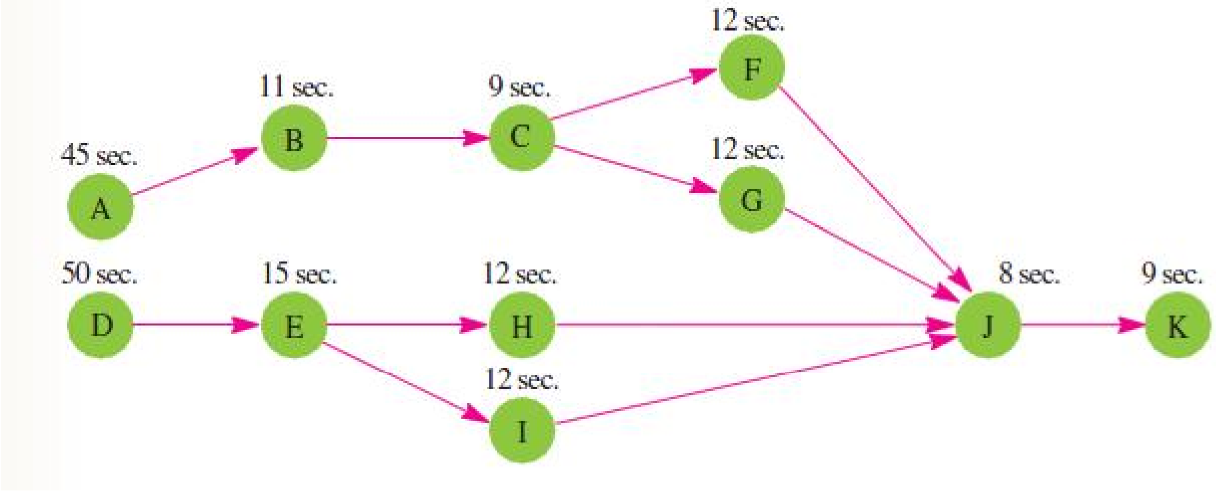
1. Draw a precedence diagram. Exhibit TN5.11 Illustrates the sequential relationships identified in Exhibit TN5.10(The length of the arrows has no meaning.)

Example TN5.2 (cont.)



Task	Task Time (in Seconds)	Description	Tasks That Must Precede
A	45	Position rear axle support and hand fasten four screws to nuts.	—
B	11	Insert rear axle.	A
C	9	Tighten rear axle support screws to nuts.	B
D	50	Position front axle assembly and hand fasten with four screws to nuts.	—
E	15	Tighten front axle assembly screws.	D
F	12	Position rear wheel #1 and fasten hubcap.	C
G	12	Position rear wheel #2 and fasten hubcap.	C
H	12	Position front wheel #1 and fasten hubcap.	E
I	12	Position front wheel #2 and fasten hubcap.	E
J	8	Position wagon handle shaft on front axle assembly and hand fasten bolt and nut.	F, G, H, I
K	9	Tighten bolt and nut.	J
	195		

Example TN5.2 (cont.)



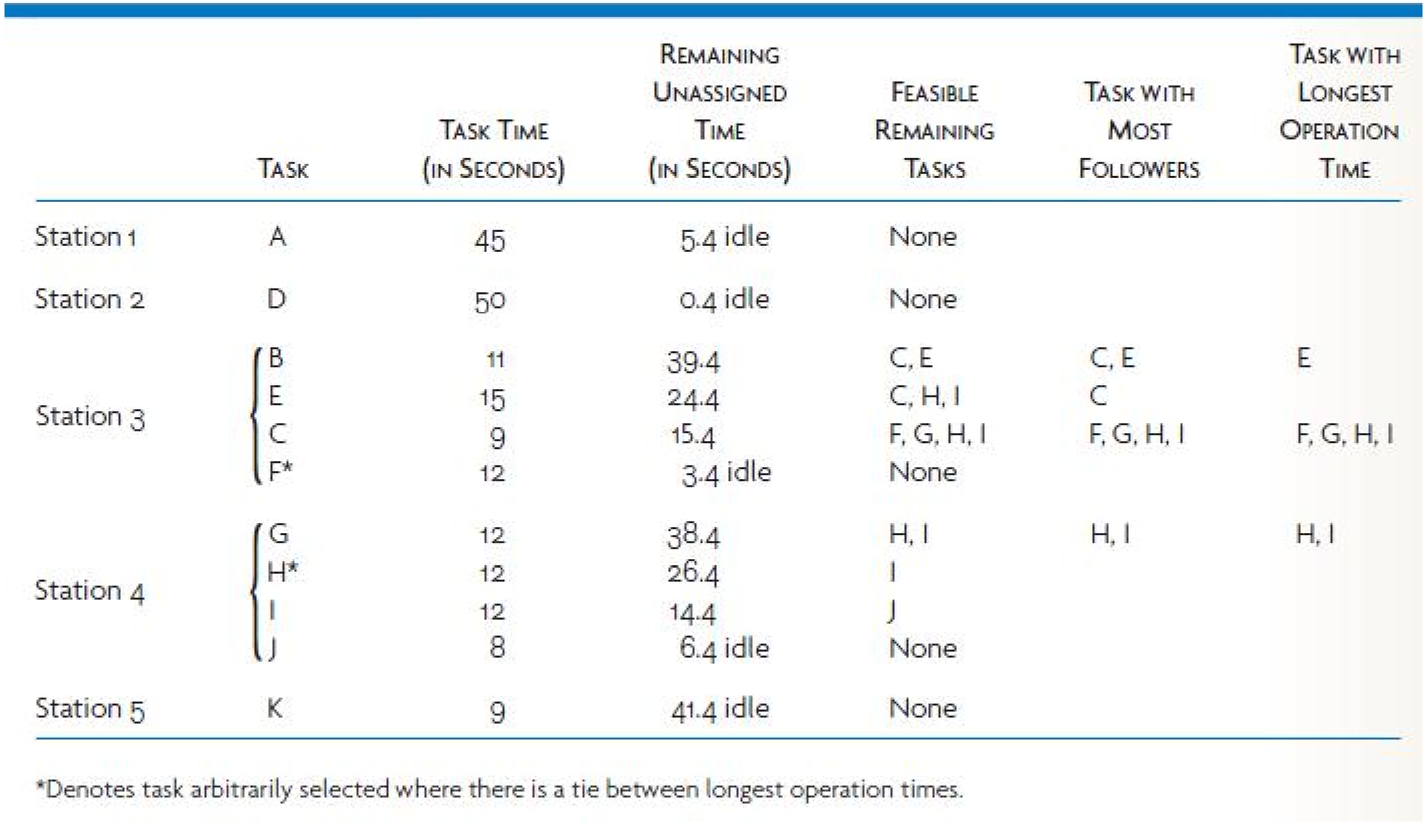
2 Determine workstation cycle time. Here we have to convert to seconds because our task times are in seconds.

$$C = \frac{\text{Production time per day}}{\text{Output per day}} = \frac{60 \text{ sec.} \times 420 \text{ min.}}{500 \text{ wagons}} = \frac{25,200}{500} = 50.4$$

3 Determine the theoretical minimum number of workstations required (the actual number may be greater):

$$N_t = \frac{T}{C} = \frac{195 \text{ seconds}}{50.4 \text{ seconds}} = 3.87 = 4 \text{ (rounded up)}$$

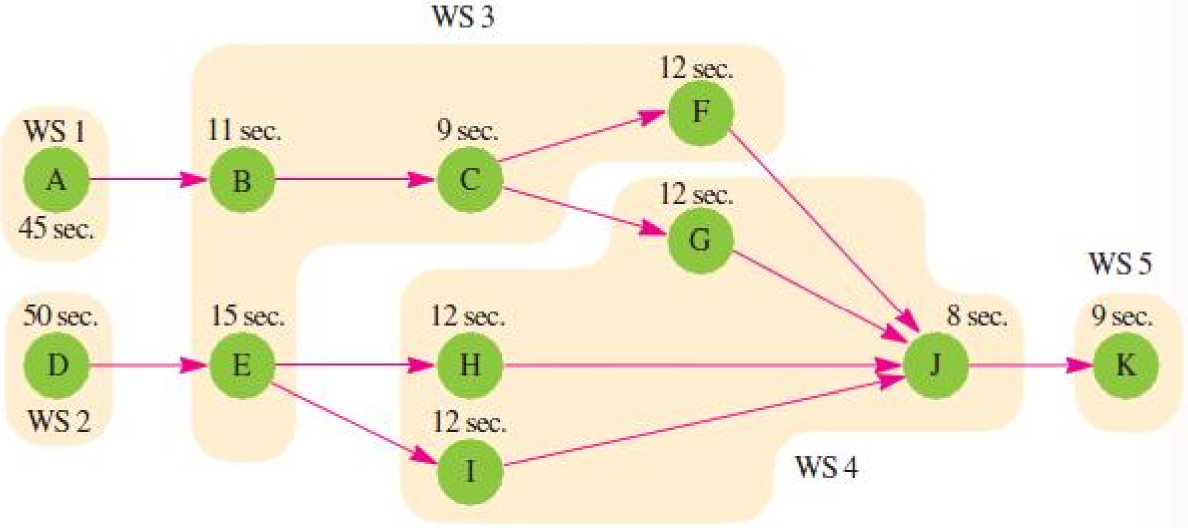
Example TN5.2 (cont.)



	Task	Task Time (in Seconds)	Remaining Unassigned Time (in Seconds)	Feasible Remaining Tasks	Task with Most Followers	Task with Longest Operation Time
Station 1	A	45	5.4 idle	None		
Station 2	D	50	0.4 idle	None		
Station 3	B	11	39.4	C, E	C, E	E
	E	15	24.4	C, H, I	C	
	C	9	15.4	F, G, H, I	F, G, H, I	F, G, H, I
	F*	12	3.4 idle	None		
Station 4	G	12	38.4	H, I	H, I	H, I
	H*	12	26.4	I		
	I	12	14.4	J		
	J	8	6.4 idle	None		
Station 5	K	9	41.4 idle	None		

*Denotes task arbitrarily selected where there is a tie between longest operation times.

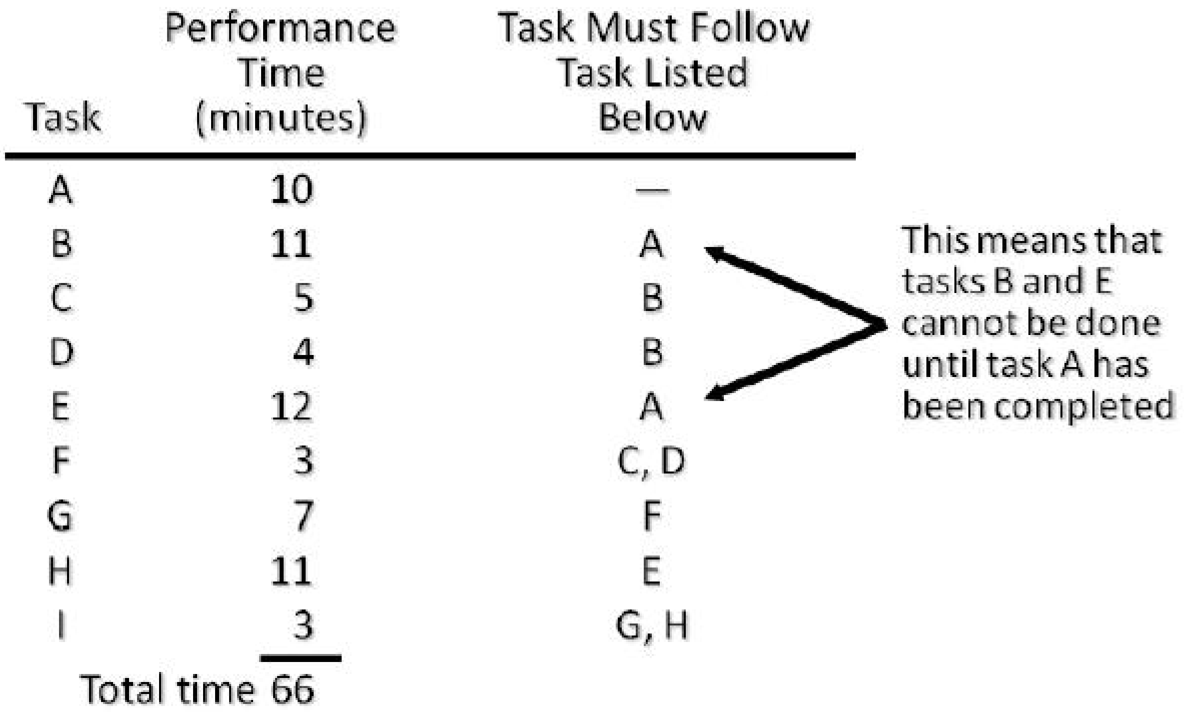
Example TN5.2 (cont.)



$$\text{Efficiency} = \frac{T}{N_aC} = \frac{195}{(5)(50.4)} = .77\text{, or }77\%$$

Ex 03

Firm determines that there are 480 productive minutes are available per day. The production schedule requirement is 40 units be completed as output from the assembly line each day. Determine cycle time, number of work stations, efficiency.

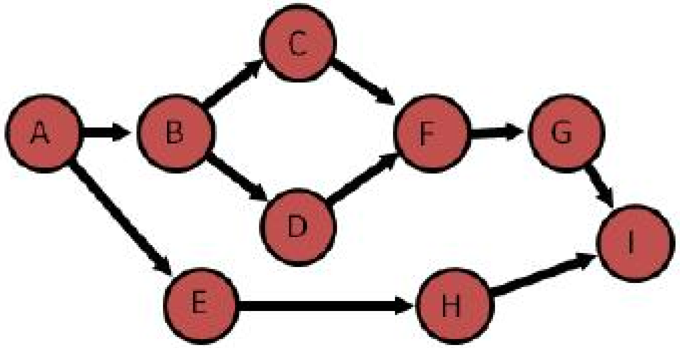


Task	Performance Time (minutes)	Task Must Follow Task Listed Below
A	10	—
B	11	A
C	5	B
D	4	B
E	12	A
F	3	C, D
G	7	F
H	11	E
I	3	G, H
Total time	66	

This means that tasks B and E cannot be done until task A has been completed

Ex 03 (cont.)

Task	Performance Time (minutes)	Task Must Follow Task Listed Below
A	10	—
B	11	A
C	5	B
D	4	B
E	12	A
F	3	C, D
G	7	F
H	11	E
I	3	G, H
Total time	66	



Ex 03 (cont.)

$$CT = \text{cycle time} = \frac{\text{Production time available per day}}{\text{Units required per day}}$$

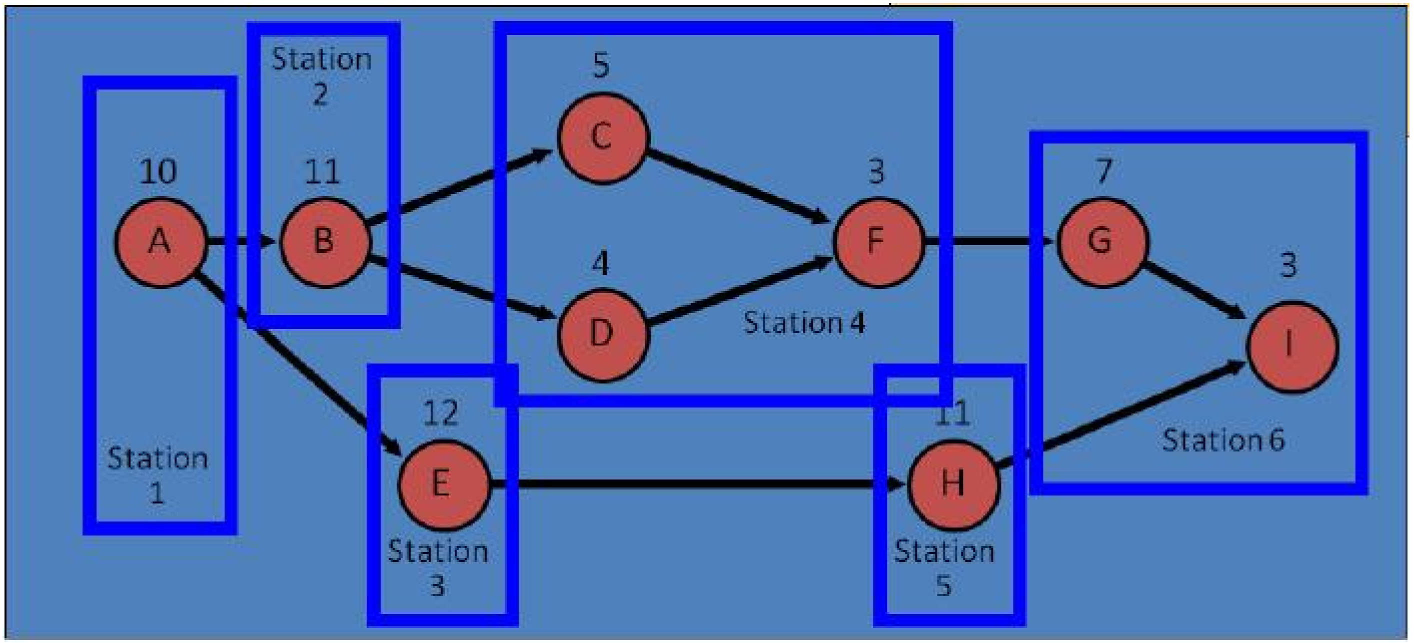
$$= \frac{480}{40}$$

$$= 12 \text{ min}$$

$$N = \frac{66}{12}$$

$$= 5.5 \text{ or } 6 \text{ stations}$$

Ex 03 (cont.)


Station 2
5
C
10
11
3
7
A
B
F
G
3
4
D
Station 4
I
12
11
Station 1
E
H
Station 6
Station 3
Station 5

Ex 03 (cont.)

$$\text{Efficiency} = \frac{\text{Task time}}{\text{(actual number of workstations) x (largest cycle time)}}$$

$$= \frac{\text{66 minutes}}{\text{(6 stations) x (12 minutes)}}$$

$$= \quad 91.7\ \%$$

Ex 04

The Toy company has decided to manufacture a new toy, the production of Which is broken into six steps. The demand for toy is 4800 units per 40 hour-week

a) Draw a precedence diagram of this operation

b) Given the demand, what is the cycle time of operation ?

c) What is theoretical minimum number of workstations ?

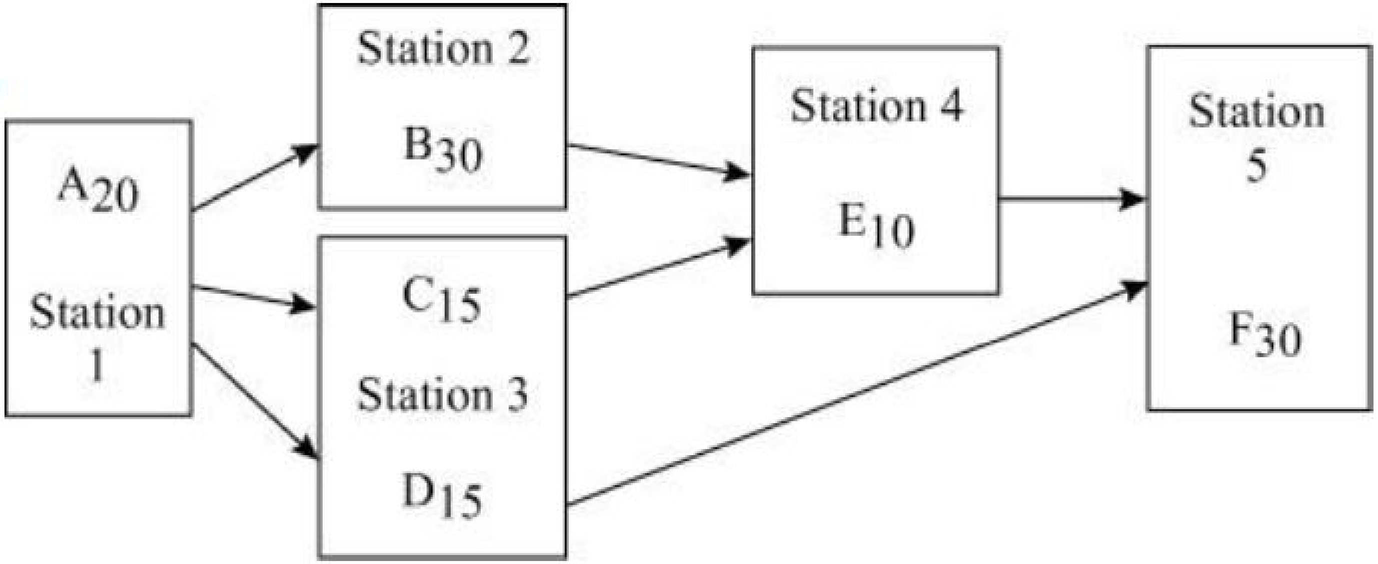
d) Assign tasks to workstations ?

e) What is efficiency of the assembly line if number of station 4, 5 or 6 ?

Task	**Performance Time (in seconds)**	**Predecessors**
A	20	None
B	30	A
C	15	A
D	15	A
E	10	B,C
F	30	D,E

Ex 04

(a)



$$\text{(b) cycle time} = \left(\frac{40\text{ hr.}}{4{,}800\text{ units}}\right)\left(\frac{60\text{ min}}{\text{hr.}}\right)\left(\frac{60\text{ sec.}}{\text{min.}}\right)$$

$$= 30\text{ sec. per unit}$$

(c) Σt/CT = 120/30 = 4 stations is theoretical minimum

Ex 04

(d)

The assembly line balance for a cycle time of 30 seconds requires five stations, as shown below and in part (a) above

Station	**Task**	**Time (sec.)**	**Time Left (sec.)**
1	A	20	10
2	B	30	
3	C	15	15
	D	15	
4	E	10	20
5	F	30	

Total idle time = 45 seconds (=10 + 15 + 20)

Ex 04

(f) If four stations were possible:

$$\text{Efficiency} = \frac{\sum t}{(\text{No. Stations})(\text{Cycle time})}$$

$$= \frac{120}{(4)(30)} = \frac{120}{120} = 1.0 = 100\%$$

With five stations:

$$\text{Efficiency} = \frac{\sum t}{(\text{No. Stations})(\text{Cycle time})}$$

$$= \frac{120}{(5)(30)} = \frac{120}{150} = .8 = 80\%$$

If six stations are used:

$$\text{Efficiency} = \frac{\sum t}{(\text{No. Stations})(\text{Cycle time})}$$

$$= \frac{120}{(6)(30)} = \frac{120}{180} = .666 = 66.6\%$$

Comparison of Product and Process Layouts

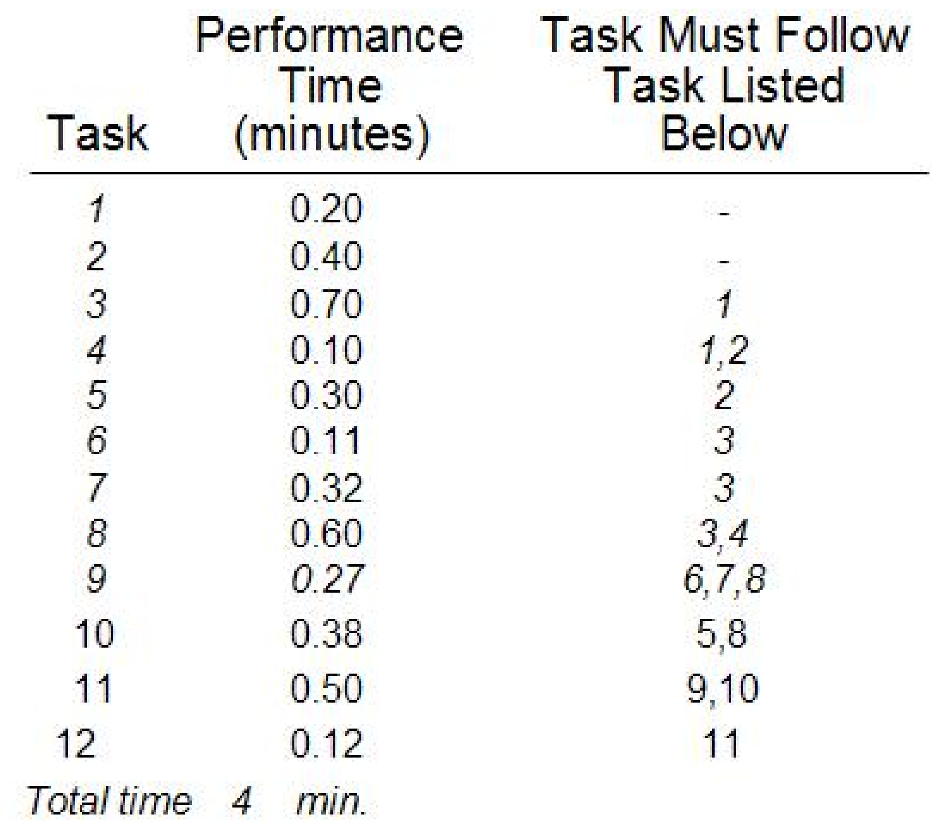
	Product	Process
Description	Sequential arrangement of activities	Functional grouping of activities
Type of process	Continuous, mass production, mainly assembly	Intermittent, job shop, batch production, mainly fabrication
Product	Standardized, made to stock	Varied, made to order
Demand	Stable	Fluctuating
Volume	High	Low
Equipment	Special purpose	General purpose

Comparison of Product and Process Layouts (cont.)

	Product	Process
Workers	Limited skills	Varied skills
Inventory	Low in-process, high finished goods	High in-process, low finished goods
Storage space	Small	Large
Material handling	Fixed path (conveyor)	Variable path (forklift)
Aisles	Narrow	Wide
Scheduling	Part of balancing /Line	Dynamic / Orders
Layout decision	Line balancing	Machine location
Goal	Equalize work at each station	Minimize material handling cost
Advantage	Efficiency	Flexibility

Ex 05

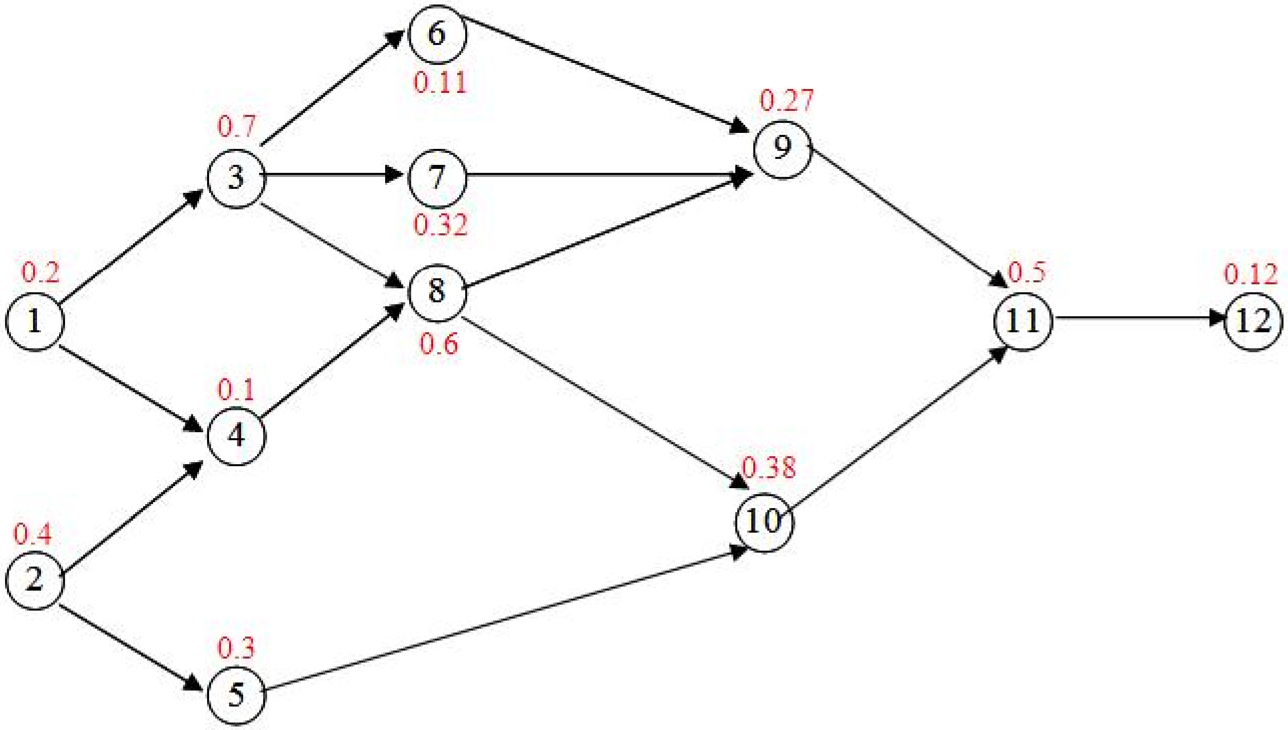
Cycle = 1 minutes



Task	Performance Time (minutes)	Task Must Follow Task Listed Below
1	0.20	-
2	0.40	-
3	0.70	1
4	0.10	1,2
5	0.30	2
6	0.11	3
7	0.32	3
8	0.60	3,4
9	0.27	6,7,8
10	0.38	5,8
11	0.50	9,10
12	0.12	11
Total time	*4 min.*	

จงทำให้ Line Balance โดยแนวคิดของ Ranked positional weight

Ex 05 (cont.)



Ex 05 (cont.)

- หาค่า Ranging ของแต่ละงานออกมาก่อน (หาเวลาของงานทั้งหมดที่ตาม + เวลาของตัวมันเอง)
- Station 12 มีเวลาของงานรวมทั้งห 0.12
- Station 11 มีเวลาของงานรวมทั้งห 0.5 + 0.12 = 0.62
- Station 10 มีเวลาของงานรวมทั้งห 0.62 + 0.38 = 1
- Station 9 มีเวลาของงานรวมทั้งห 0.27 + 0.5 + 0.12 = 0.89
- Station 8 มีเวลาของงานรวมทั้งห 0.6 + 0.27 + 0.38 + 0.5 + 0.12 = 1.87
- Station 7 มีเวลาของงานรวมทั้งห 0.32 + 0.27 + 0.5 + 0.12 = 1.21
- Station 6 มีเวลาของงานรวมทั้งห 0.11 + 0.27 + 0.5 + 0.12 = 1
- Station 5 มีเวลาของงานรวมทั้งห 0.3 + 0.38 + 0.5 + 0.12 = 1.3
- Station 4 มีเวลาของงานรวมทั้งห 0.1 + 0.6 + 0.38 + 0.27 + 0.5 + 0.12 = 1.97
- Station 3 มีเวลาของงานรวมทั้งห 0.7 + 0.11 + 0.32 + 0.6 +0.27 + 0.38 + 0.5 +0.12 = 3
- Station 2 มีเวลาของงานรวมทั้งห 0.4 + 0.1 + 0.3 + 0.6 + 0.38 +0.27 + 0.5 + 0.12 = 2.67
- Station 1 มีเวลาของงานรวมทั้งห 0.2 + 0.7 + 0.1 +0.11 + 0.32 + 0.6 + 0.38 +0.27 + 0.5 + 0.12 = 3.3

Ex 05 (cont.)

Station	Job	Time (นาที)	Total Time (นาที)	Idle time
1	1 3	0.2 0.7	0.9	(1 -0.9) = 0.1
2	2 4 5 6	0.4 0.1 0.3 0.11	0.91	(1 -0.91) = 0.09
3	8 7	0.6 0.32	0.92	(1 -0.92) = 0.08
4	10 9	0.38 0.27	0.65	(1 -0.65) = 0.35
5	11 12	0.5 0.12	0.62	(1 -0.62) = 0.38

รวม 1

$$\text{Percent idle time} = \frac{\text{Idle time per cycle}}{(N)(CT)}$$
$$= \frac{1}{5 \times 0.92}$$
$$= 21.7\ \%$$

$$\text{Efficiency} = 100 - \text{Percent idle time}$$
$$= 100 - 21.7$$
$$= 78.26\ \%$$

Homework

กำหนดให้ cycle Time = 1 นาที

จงทำให้ Line Balance โดยแนวคิดของ Longest task time method (ให้เลือกงานที่ต้องเวลามากมาทำก่อน)

Task	Performance Time (minutes)	Task Must Follow Task Listed Below
1	0.5	-
2	0.3	1
3	0.8	1
4	0.2	2
5	0.1	2
6	0.6	3
7	0.4	4,5
8	0.5	3,5
9	0.3	7,8
10	0.6	6,9
Total time	4.3	min.