

Chapter 8

Facility Layout

Learning Objectives

- 8-1: Analyze the common types of manufacturing layouts.
- 8-2: Illustrate layouts used in nonmanufacturing settings.

Layout Decisions (1 of 2)

- **Facility layout:** the process of determining placement of departments, workgroups within departments, workstations, machines, and stock-holding points within a facility

Layout Decisions (2 of 2)

- This process requires the following inputs:
 1. Specification of the objectives used to evaluate the design
 2. Estimates of product or service demand
 3. Processing requirements
 4. Space requirements for the elements
 5. Space availability within the facility

Basic Production Layout Formats (1 of 2)

- Workcenter
 - Also called a job-shop or functional layout
 - Similar equipment are grouped together
- Assembly line
 - Also called a flow-shop layout
 - Work processes are arranged according to the steps by which the product is made

Basic Production Layout Formats (2 of 2)

- Manufacturing cell
 - Dissimilar machines are grouped to work on similar products
- Project layout
 - Product remains at one location

Workcenter Layout

- Given
 - The flow (number of moves) to and from all departments
 - The cost of moving from one department to another
 - The existing or planned physical layout of the plant
- Determine
 - The “best” locations for each department, where best means maximizing flow, which minimizes costs

Example 8.1: Toy Factory

- Goal is to arrange eight workcenters to minimize interdepartmental handling cost
- Assume all workcenters have same space and fit in building
- All material is transported in standard crates by forklift
- Transportation costs are \$1 to move between adjacent workcenters
 - Extra \$1 for each workcenter in between

Steps

1. Illustrate the interworkcenter flow by a model
2. Determine the cost of this layout
3. Search for workcenter location changes that will reduce costs

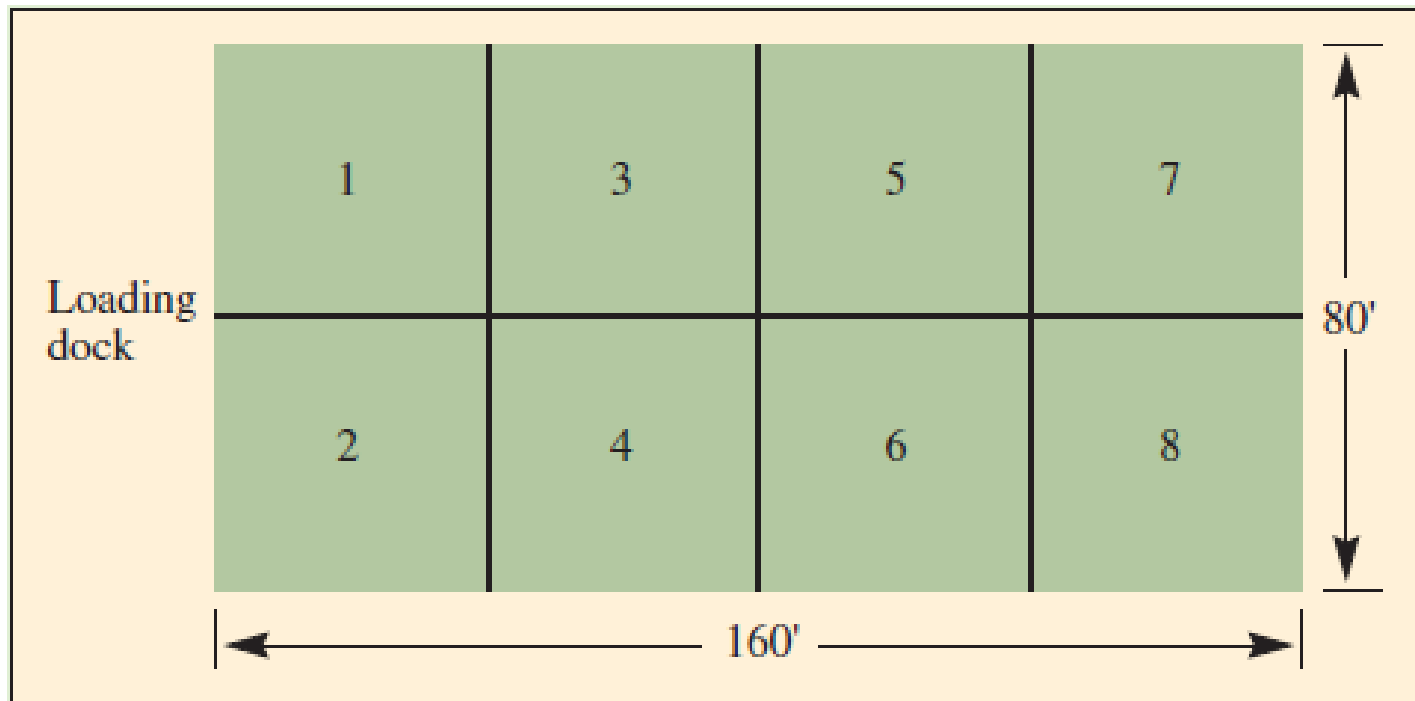
Example 8.1: Interworkcenter Flow, and Building Dimensions and Workcenters (1 of 2)

Exhibit 8.1

Flow between Workcenters (Number of Moves)								Workcenter	Activity	
	1	2	3	4	5	6	7	8		
1		175	50	0	30	200	20	25	1	Shipping and receiving
2			0	100	75	90	80	90	2	Plastic molding and stamping
3				17	88	125	99	180	3	Metal forming
4					20	5	0	25	4	Sewing department
5						0	180	187	5	Small toy assembly
6							374	103	6	Large toy assembly
7								7	7	Painting
8									8	Mechanism assembly

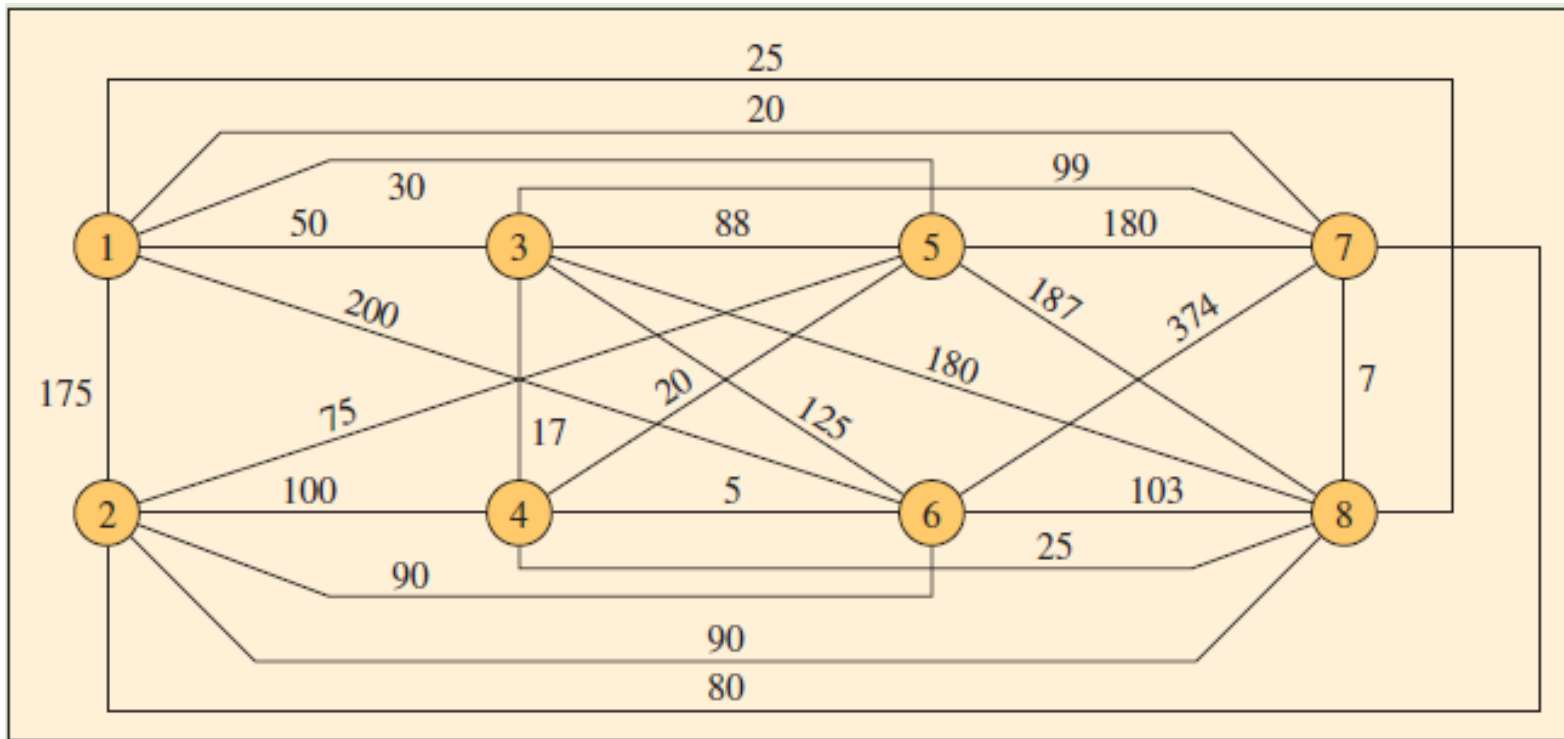
Example 8.1: Interworkcenter Flow, and Building Dimensions and Workcenters (2 of 2)

Exhibit 8.2



Example 8.1: Interworkcenter Flow Graph with Number of Annual Movements

Exhibit 8.2



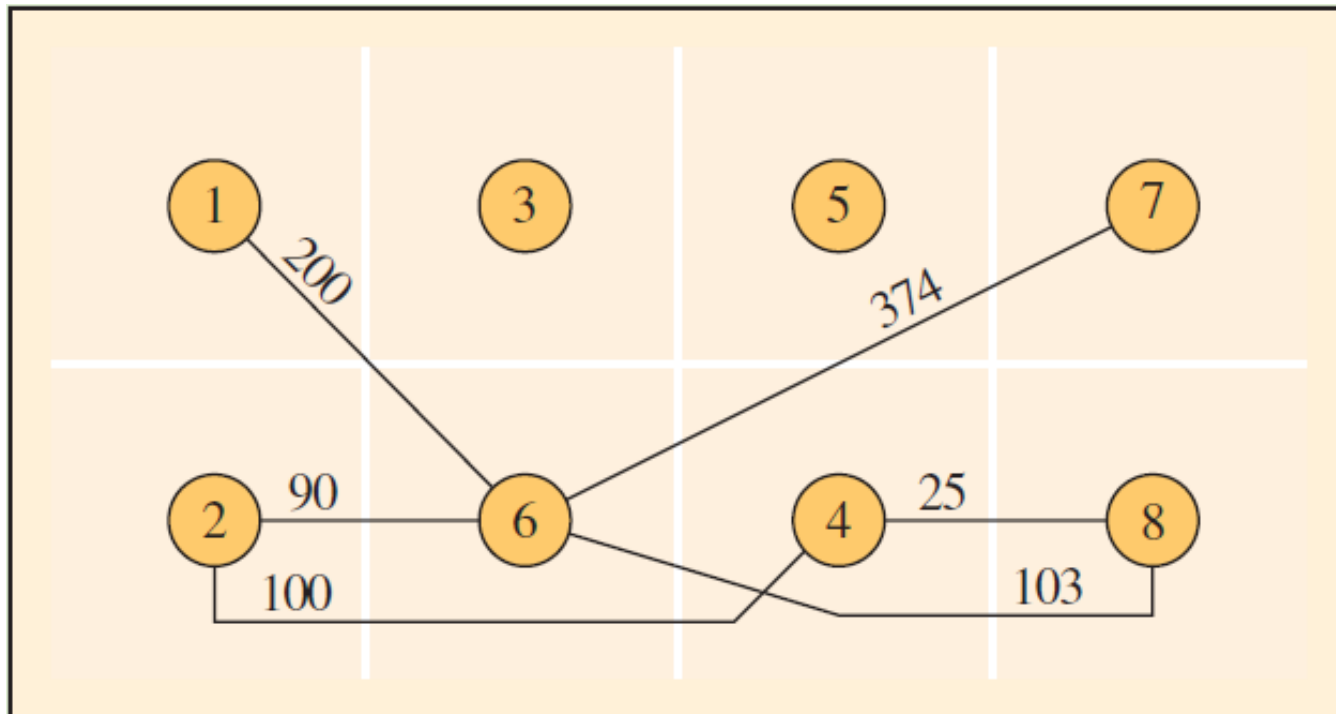
Example 8.1: Cost Matrix–First Solution

Exhibit 8.4

\$	1	2	3	4	5	6	7	8
1		175	50	0	60	400	60	75
2			0	100	150	180	240	270
3				17	88	125	198	360
4					20	5	0	50
5						0	180	187
6							374	103
7								7
8								
Total cost: \$3,474								

Example 8.1: Revised Interworkcenter Flowchart and Cost Matrix-Second Solution (1 of 2)

Exhibit 8.5



Example 8.1: Revised Interworkcenter Flowchart and Cost Matrix–Second Solution (2 of 2)

Exhibit 8.6

	1	2	3	4	5	6	7	8	Net cost change
1		175	50	0	60	(200)	60	75	–\$200
2			0	(200)	150	(90)	240	270	+ 10
3				17	88	125	198	360	
4					20	5	0	(25)	– 25
5						0	180	187	
6							(748)	(206)	+ \$374, + \$103
7								7	
8									
									+ \$262 Total cost: \$3,736

Systematic Layout Planning (1 of 2)

- Numerical flow of items between workcenters
 - Can be impractical to obtain
 - Does not account for the qualitative factors that may be crucial to the placement decision

Systematic Layout Planning (2 of 2)

- Systematic layout planning
 - Accounts for the importance of having each department located next to every other department
 - Is also guided by trial and error
 - Switching workcenters then checking the results of the “closeness” score

Systematic Layout Planning for a Floor of a Department Store

Exhibit 8.8

A. Relationship Chart (based on Tables B and C)

From	To				Area (sq. ft.)
	2	3	4	5	
1. Credit department	I 6	U —	E 4	U —	100
2. Toy department		U —	I 1	A 1.6	400
3. Wine department			U —	X 1	300
4. Camera department				X I	100
5. Candy department					100

Letter Closeness rating
Number Reason for rating

B.

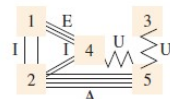
CODE	REASON*
1	Type of customer
2	Ease of supervision
3	Common personnel
4	Contact necessary
5	Share same space
6	Psychology

*Others may be used.

C.

VALUE	CLOSENESS	LINE CODE*	NUMERICAL WEIGHTS
A	Absolutely necessary	=====	16
E	Especially important	=====	8
I	Important	=====	4
O	Ordinary closeness OK	=====	2
U	Unimportant	=====	0
X	Undesirable	=====	-80

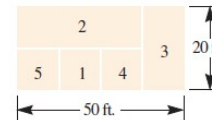
*Used for example purposes only.



Initial relationship diagram
(based on Tables A and C)



Initial layout based on
relationship diagram
(ignoring space and
building constraints)



Final layout adjusted by square
footage and building size

Assembly Line (1 of 2)

- **Assembly line:** progressive assembly linked by some material handling device
 - Some form of pacing is present and the allowable processing time is equivalent for all workstations

Assembly Line (2 of 2)

- Important differences:
 - Material handling devices
 - Line configuration
 - Pacing
 - Product mix
 - Workstation characteristics
 - Length

Assembly-Line Design

- **Cycle time:** a uniform time interval in which a moving conveyor passes a series of workstations
 - Also the time between successive units coming off the line
- **Assembly-line balancing:** assigning all tasks to a series of workstations so that each workstation has no more than can be done in the cycle time
- **Precedence relationship:** the order in which tasks must be performed in the assembly process

Assembly-Line Balancing

1. Specify the sequential relationships among tasks
2. Determine the required cycle time
3. Determine the theoretical minimum number of workstations
4. Select a primary and secondary assignment rule
5. Assign tasks
6. Evaluate the efficiency of the balance
7. Rebalance if needed

Assembly-Line Balancing Formula

$$\text{Cycle time } C = \frac{\text{Production time per day}}{\text{Required output per day (in units)}}$$

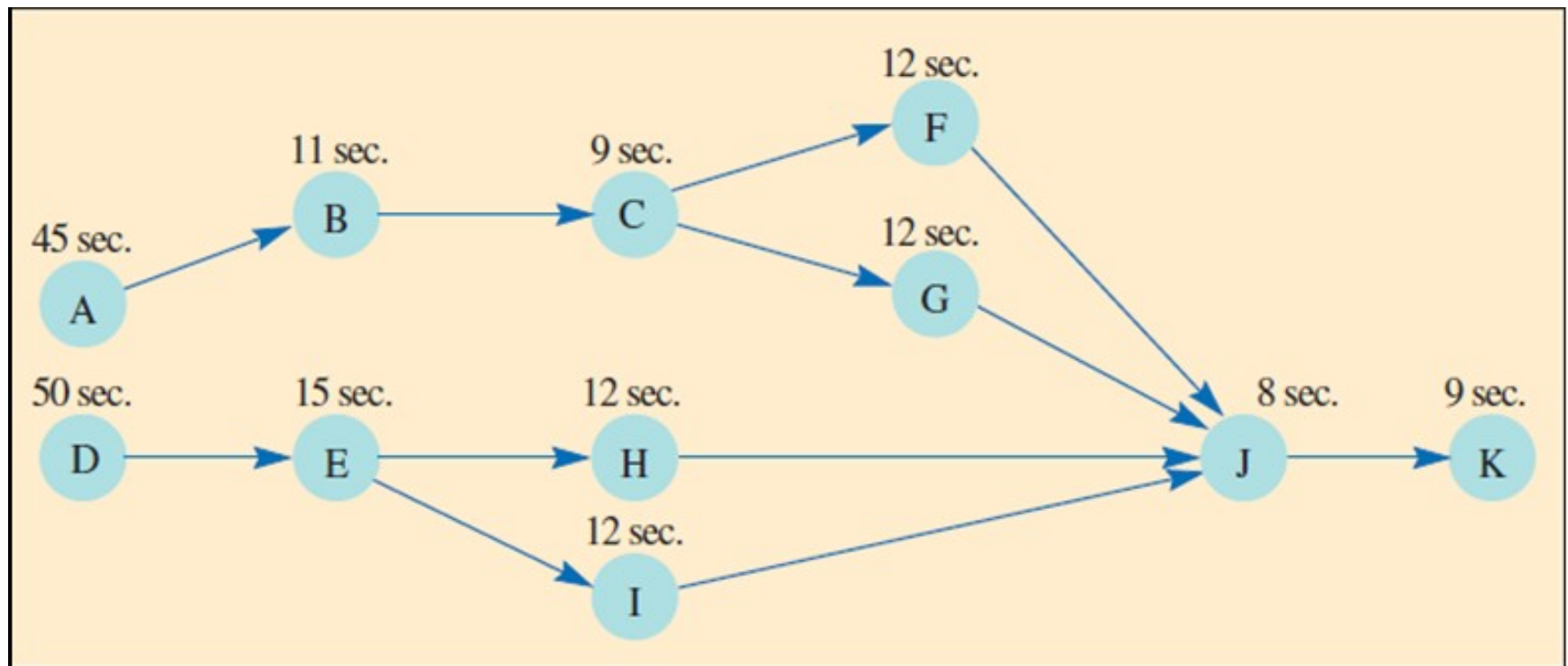
$$\text{Theoretical minimum } N_t = \frac{\text{Sum of task times (T)}}{\text{Cycle time (C)}}$$

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

Exhibit 8.9A Example 8.2: Assembly Steps and Times

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		

Exhibit 8.9B Example: Precedence Graph



Example: C and N_t

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

Exhibit 8.10 A and B Example: Assignment (1 of 2)

	Task	Task Time (in seconds)	Remaining Unassigned Time (in Seconds)	Feasible Remaini ng 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
Station 3	E	15	24.4	C, H, I	C	
Station 3	C	9	15.4	F, G, H, I	F, G, H, I	F, G, H, I
Station 3	F*	12	3.4 idle	None		
Station 4	G	12	38.4	H,I	H,I	H,I
Station 4	H*	12	26.4	I		
Station 4	I	12	14.4	J		
Station 4	J	8	6.4 idle	None		
Station 5	K	9	41.4 idle	None		

Exhibit 8.10 A and B Example: Assignment (2 of 2)

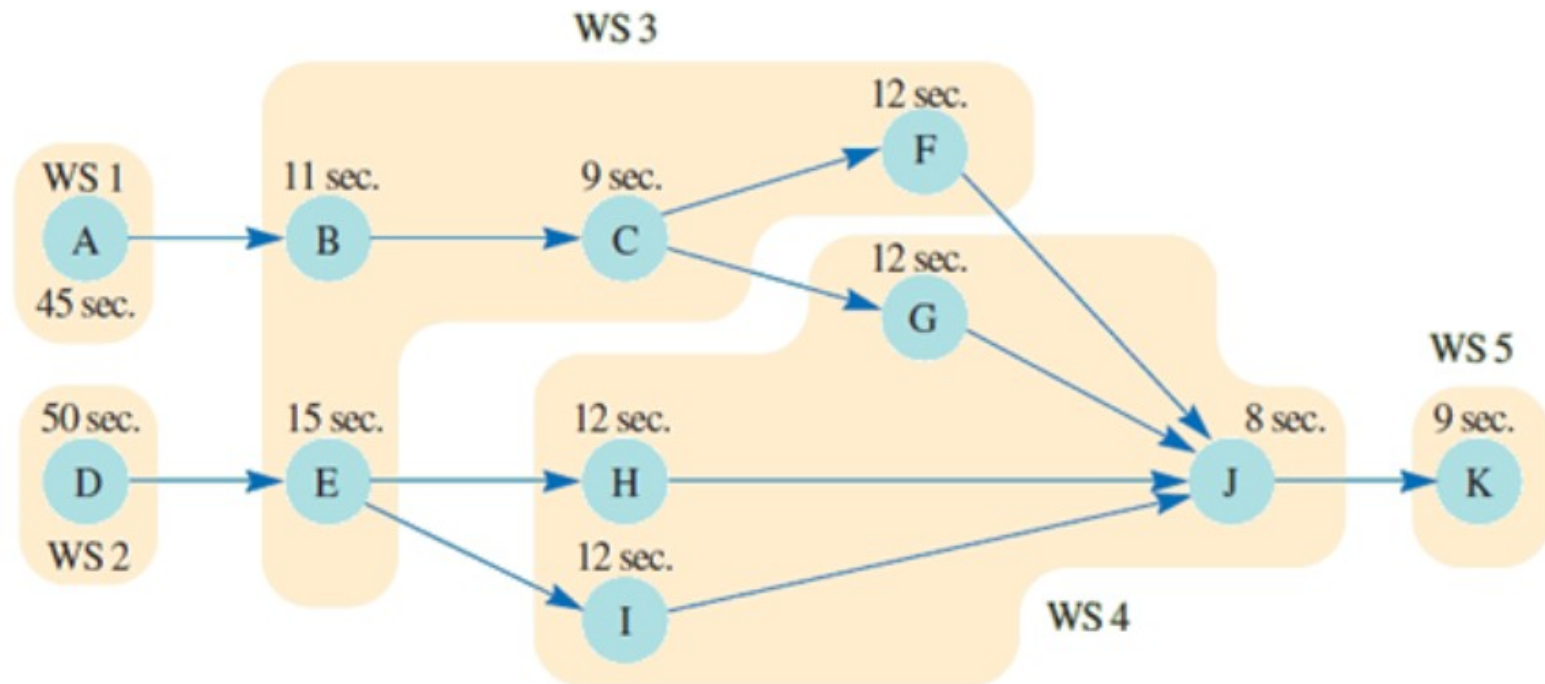


Exhibit 8.10C Example: Efficiency

$$\text{Efficiency} = \frac{T}{N_a C} = \frac{195}{5(50.4)} = 0.77 = 77\%$$

Splitting Tasks That Are Too Long for the Cycle Time (1 of 2)

1. Split the task

- Can we split the task into two different tasks

2. Share the task

- Can an adjacent workstation do part of the work

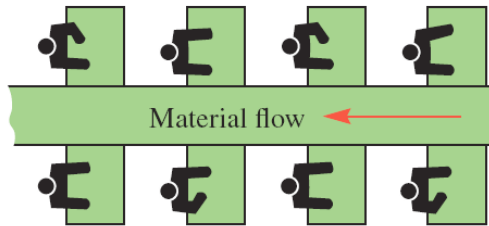
3. Use parallel workstations

- Using parallel workstations doubles the cycle time available for the task

Splitting Tasks That Are Too Long for the Cycle Time (2 of 2)

4. Use a more skilled worker
 - Can a more skilled worker complete the task faster
5. Work overtime
 - Use longer cycle time and make up needed production using overtime
 - Affects all workstations
6. Redesign
 - Can we redesign the product to save time

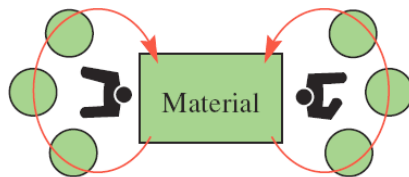
Exhibit 8.11 Partial Flexible Line Layouts (1 of 2)



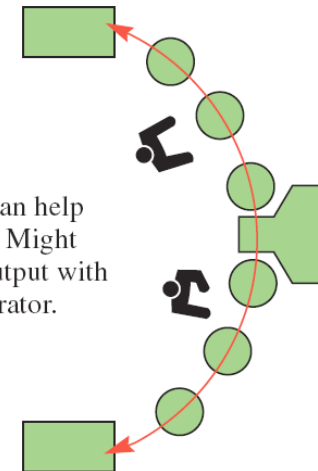
Bad: Operators caged. No chance to trade elements of work between them.
(Subassembly-line layout common in American plants.)



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

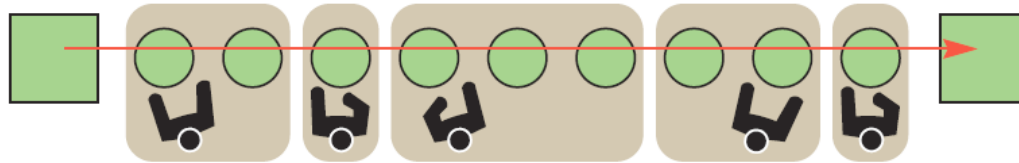


Bad: Operators birdcaged. No chance to increase output with a third operator.



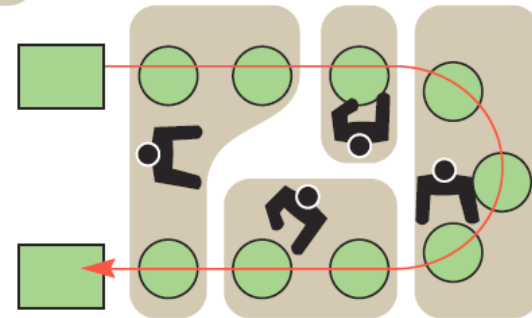
Better: Operators can help each other. Might increase output with a third operator.

Exhibit 8.11 Partial Flexible Line Layouts (2 of 2)



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.



Mixed-Model Line Balancing (1 of 2)

- Most factories produce a number of different products
 - Inventory can be reduced by building some of each product during every period (e.g., day, week, etc.)
- Mixed-model line balancing is one means of scheduling this varied production
- Used by JIT manufacturers
- Objective is to meet demand and avoid high inventories

Mixed-Model Line Balancing (2 of 2)

- This approach often requires diligent efforts to reduce setup times and costs
- Can significantly reduce overall inventory levels

Example 8.3: Mixed-Model Line Balancing (1 of 2)

- Processing must be completed for both Model J and Model K wagons
- Equal number of each model are required
- Cycle time is 6 minutes for Model J and 4 minutes for Model K
- In an 8-hour day, how should the models be processed?
- We know $6K + 4J = 480$ and $K = J$
 - Solving gives us $K = J = 48$ per day or 6 per hour

Example 8.3: Mixed-Model Line Balancing (2 of 2)

Balanced Mixed-Model Sequence					Repeats 8 times per day
Model sequence	J J	K K K	J J	J J	
Operation time	6 6	4 4 4	6 6	6 6	
Minicycle time	12	12	12	12	
Total cycle time	60				

- Line balanced at six frames of each time per hour with a mini-cycle time of 12 minutes
- Another balance is JKKJKJ
 - Times of 6, 4, 4, 6, 4, 6
 - Produces 3J and 3K every 30 minutes with 10 minute mini-cycle time

Cells

- Cellular layouts allocate dissimilar machines into cells
- Widely used in metal fabricating, computer chips manufacture, and assembly work
- Objective is to gain the benefits of assembly lines with workcenter kinds of production
 1. Better human relations
 2. Improved operator expertise
 3. Less in-process inventory and material handling
 4. Faster production setup

Developing a Manufacturing Cell

1. Grouping parts into families that follow a common sequence of steps
2. Identifying dominant flow patterns of parts families as a bases for location of processes
3. Physically grouping machines and processes into cells

Exhibit 8.12A Example: Original Workcenter Layout

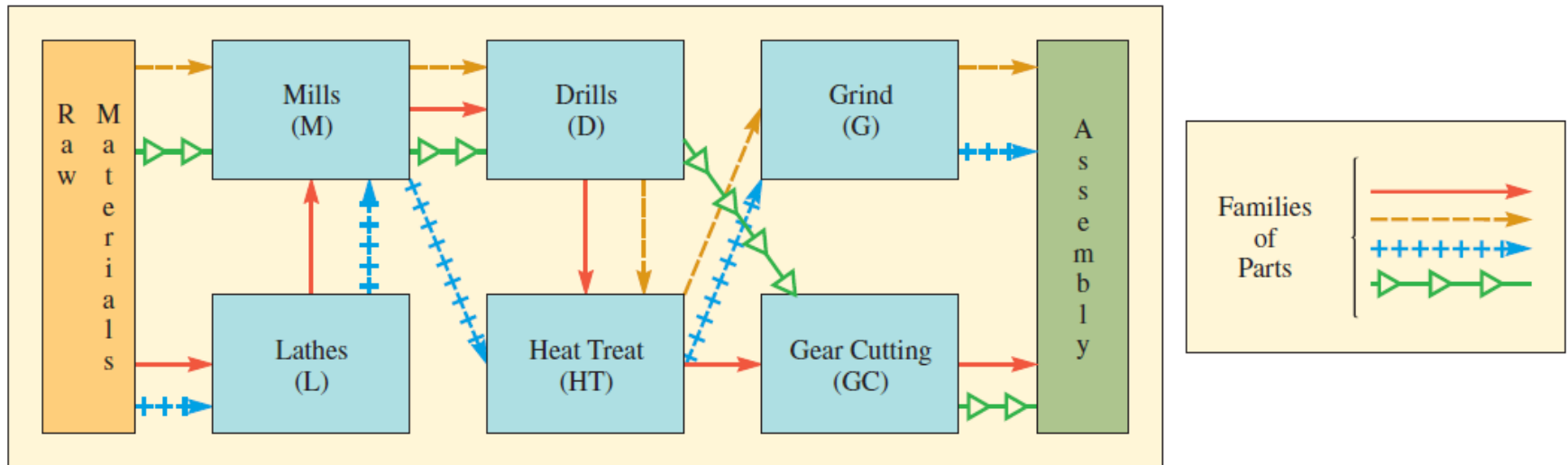
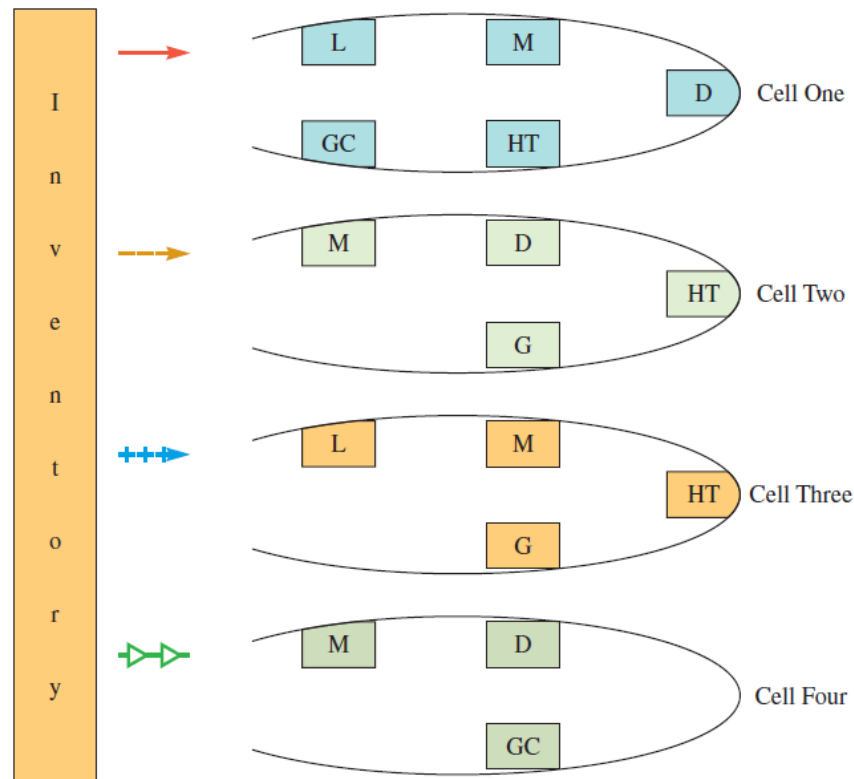


Exhibit 8.12B Example: Routing Matrix Based upon Flow of Parts

Raw Materials	Part Family	Lathes	Mills	Drills	Heat Treating	Grinders	Gear Cutting	To	Assembly
			X	X	X	X			
			X	X			X		
		X	X	X	X		X		
		X	X		X	X			

Exhibit 8.12C Example: Reallocating Machines to Form Cells



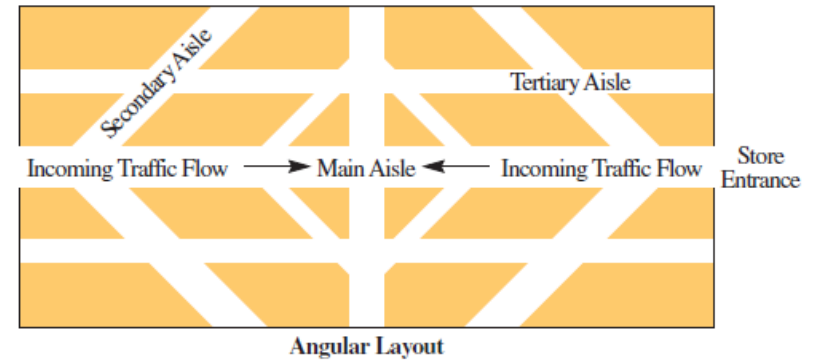
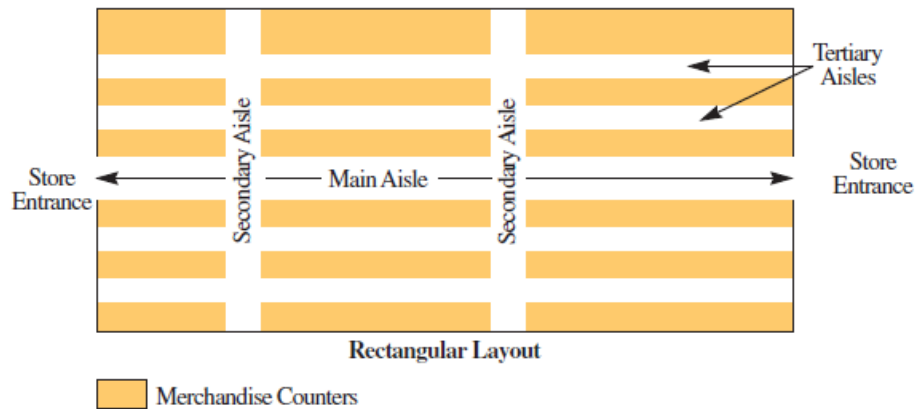
Project Layout

- Is characterized by a relatively low number of production units
- Visualize the product as the hub of a wheel with materials and equipment arranged concentrically around the production point
- A high degree of task ordering is common
- To the extent that this precedence determines production stages, a project layout might be developed by arranging materials according to their technological priority

Retail Service Layout

- Goal is to maximize net profit per square foot of floor space
- Servicescapes
 - Ambient conditions
 - Background characteristics, such as noise
 - Spatial layout and functionality
 - Planning the circulation path of customers and grouping merchandise
 - Signs, symbols, and artifacts
 - Parts of the service that have social significance

Alternative Store Layouts



Marketing Research and Retail Layout

1. People in supermarkets tend to follow a perimeter pattern in their shopping behavior
2. Sale merchandise placed at the end of an aisle in supermarkets almost always sells
3. Non-selling departments should be placed either on upper floors or in “dead” areas
4. Locations nearest the store entrances and adjacent to front window displays are most valuable

Office Layout

- More open offices
- Low divider walls
- Fewer walls fosters greater communication and teamwork
- Size and orientation of desks indicates importance of people behind them

Summary (1 of 2)

- The focus is on understanding the quantitative techniques used to design manufacturing layouts
 - Workcenter, assembly line, manufacturing cell, and project layouts
- Workcenter layouts involve arranging functional workcenters to optimize the flow between these areas

Summary (2 of 2)

- Assembly-line design is centered on defining the work content of workstations spaced along the line
 - Assembly-line balancing
- Manufacturing cells are used for lower volume settings
- Other types of layouts include those used in retail stores and offices

Practice Exam (1 of 4)

1. Three terms commonly used to refer to a layout where similar equipment or functions are grouped together
2. A layout where the work to make an item is arranged in progressive steps and work is moved between the steps at fixed intervals of time
3. A measure used to evaluate a workcenter layout

Practice Exam (2 of 4)

4. This is a way to shorten the cycle time for an assembly line that has a task time that is longer than the desired cycle time
 - Assume that it is not possible to speed up the task, split the task, use overtime, or redesign the task
5. This involves scheduling several different models of a product to be produced over a given day or week on the same line in a cyclical fashion

Practice Exam (3 of 4)

6. If you wanted to produce 20 percent of one product (A), 50 percent of another (B), and 30 percent of a third product (C) in a cyclic fashion, what schedule would you suggest
7. A term used to refer to the physical surroundings in which a service takes place and how these surroundings affect customers and employees

Practice Exam (4 of 4)

8. A firm is using an assembly line and needs to produce 500 units during an eight-hour day
 - What is the required cycle time in seconds
9. What is the efficiency of an assembly line that has 25 workers and a cycle time of 45 seconds
 - Each unit produced on the line has 16 minutes of work that needs to be completed based on a time study completed by engineers at the factory

End of Presentation