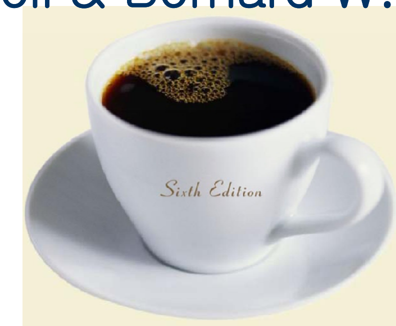
Chapter 7

Capacity and Facilities

Operations Management - 6th Edition

Roberta Russell & Bernard W. Taylor, III



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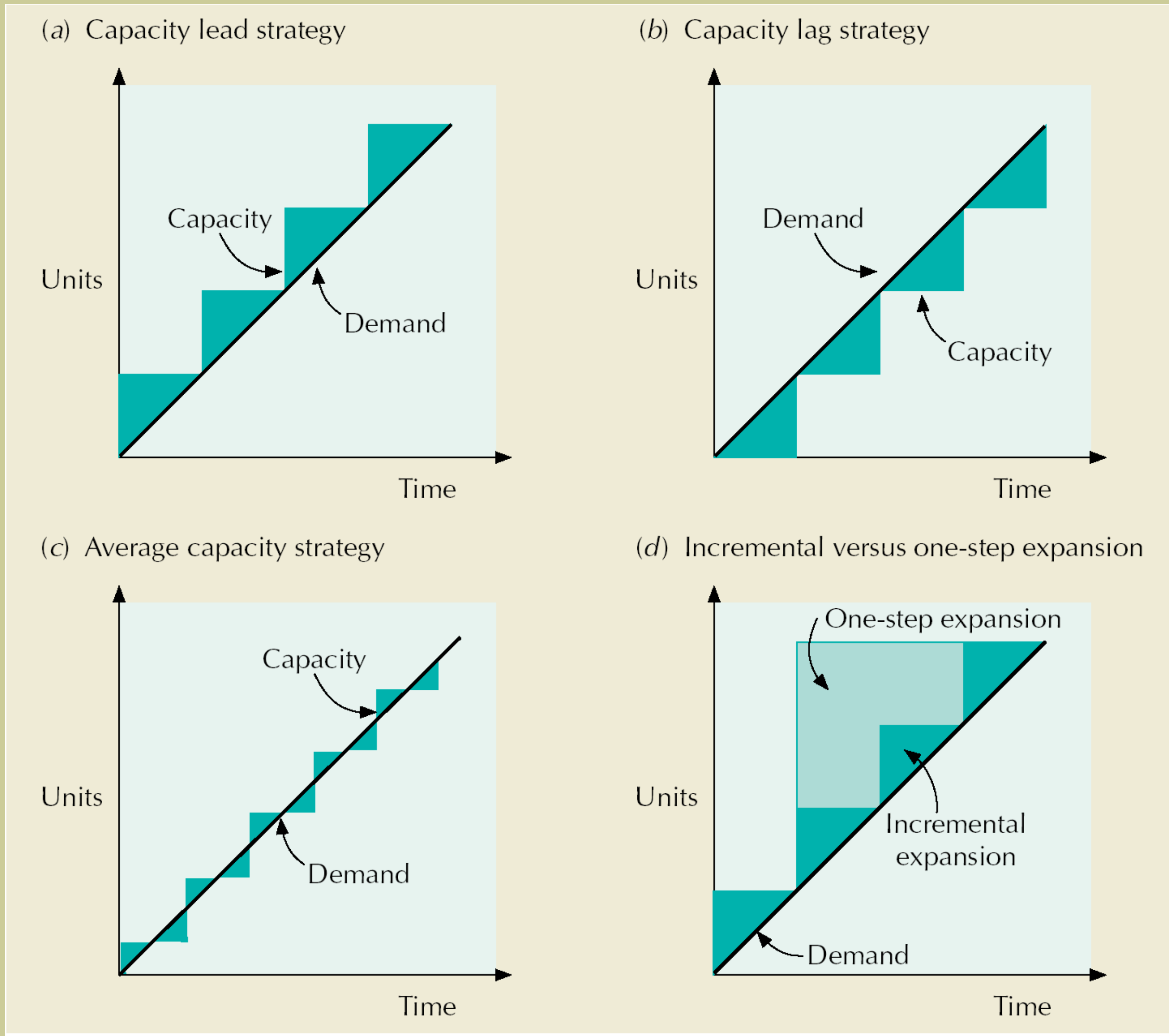
Lecture Outline

- Capacity Planning
- Basic Layouts
- Designing Process Layouts
- Designing Service Layouts
- Designing Product Layouts
- Hybrid Layouts

Capacity

- Maximum capability to produce
- Capacity planning
  - establishes overall level of productive resources for a firm
- 3 basic strategies for timing of capacity expansion in relation to steady growth in demand (lead, lag, and average)

Capacity Expansion Strategies



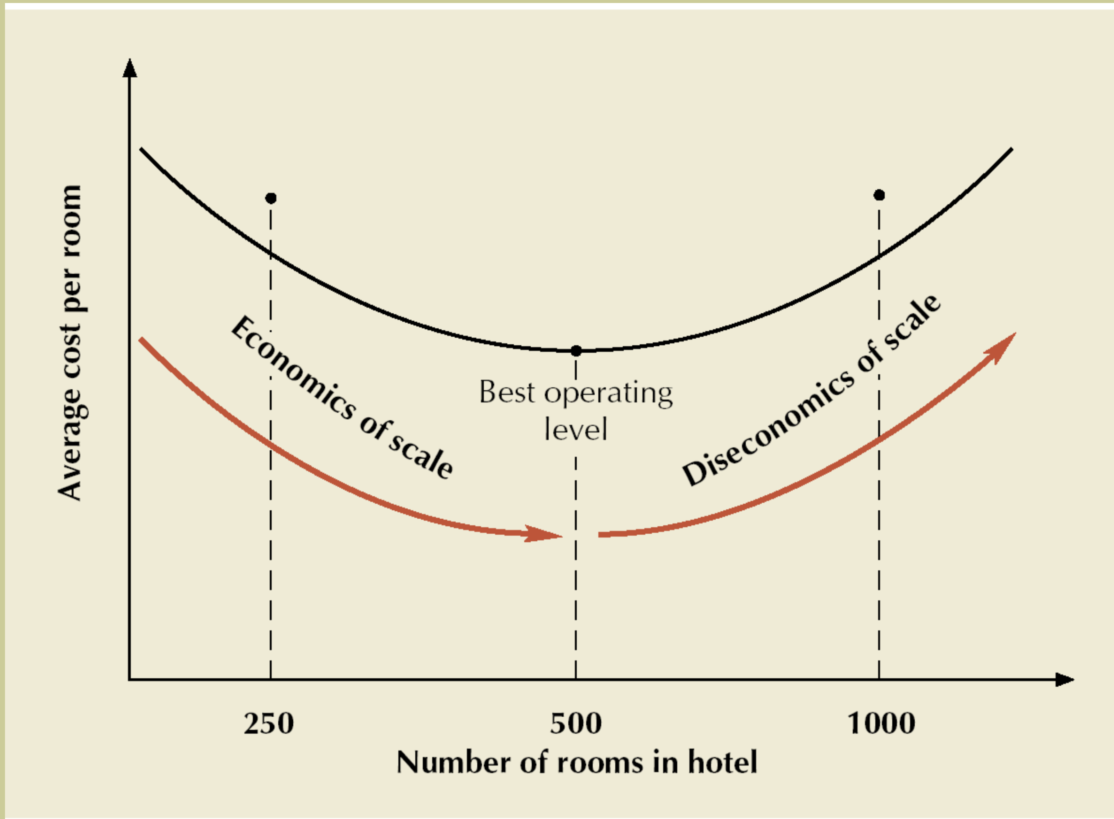
Capacity (cont.)

- Capacity increase depends on
  - volume and certainty of anticipated demand
  - strategic objectives
  - costs of expansion and operation
- Best operating level
  - % of capacity utilization that minimizes unit costs
- Capacity cushion
  - % of capacity held in reserve for unexpected occurrences

Economies of Scale

- it costs less per unit to produce high levels of output
  - fixed costs can be spread over a larger number of units
  - production or operating costs do not increase linearly with output levels
  - quantity discounts are available for material purchases
  - operating efficiency increases as workers gain experience

Best Operating Level for a Hotel



Machine Objectives of Facility Layout

Arrangement of areas within a facility to:

- Minimize material-handling costs
- Utilize space efficiently
- Utilize labor efficiently
- Eliminate bottlenecks
- Facilitate communication and interaction
- Reduce manufacturing cycle time
- Reduce customer service time
- Eliminate wasted or redundant movement
- Increase capacity
- Facilitate entry, exit, and placement of material, products, and people
- Incorporate safety and security measures
- Promote product and service quality
- Encourage proper maintenance activities
- Provide a visual control of activities
- Provide flexibility to adapt to changing conditions

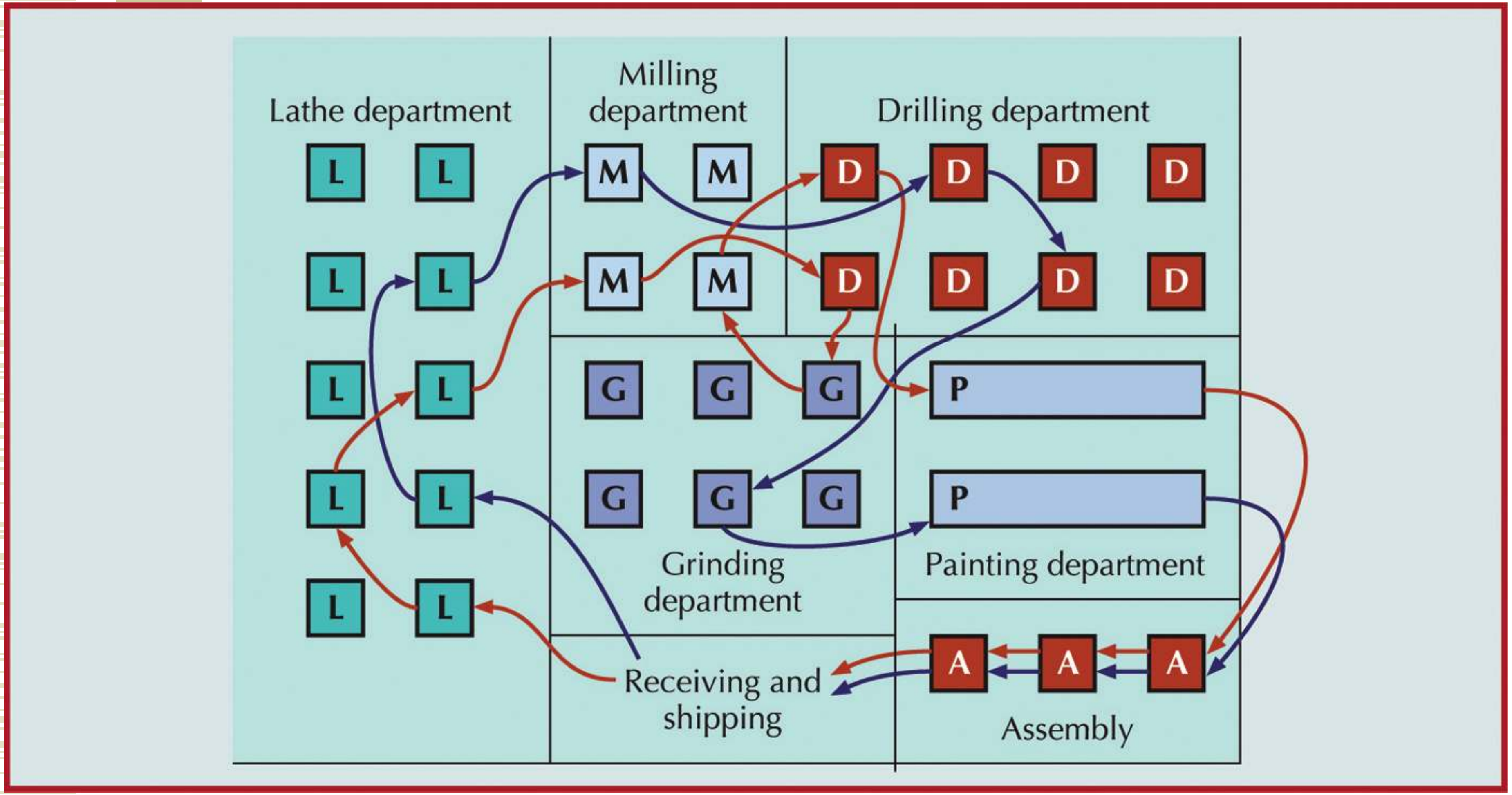
BASIC LAYOUTS

- Process layouts
  - group similar activities together according to process or function they perform
- Product layouts
  - arrange activities in line according to sequence of operations for a particular product or service
- Fixed-position layouts
  - are used for projects in which product cannot be moved

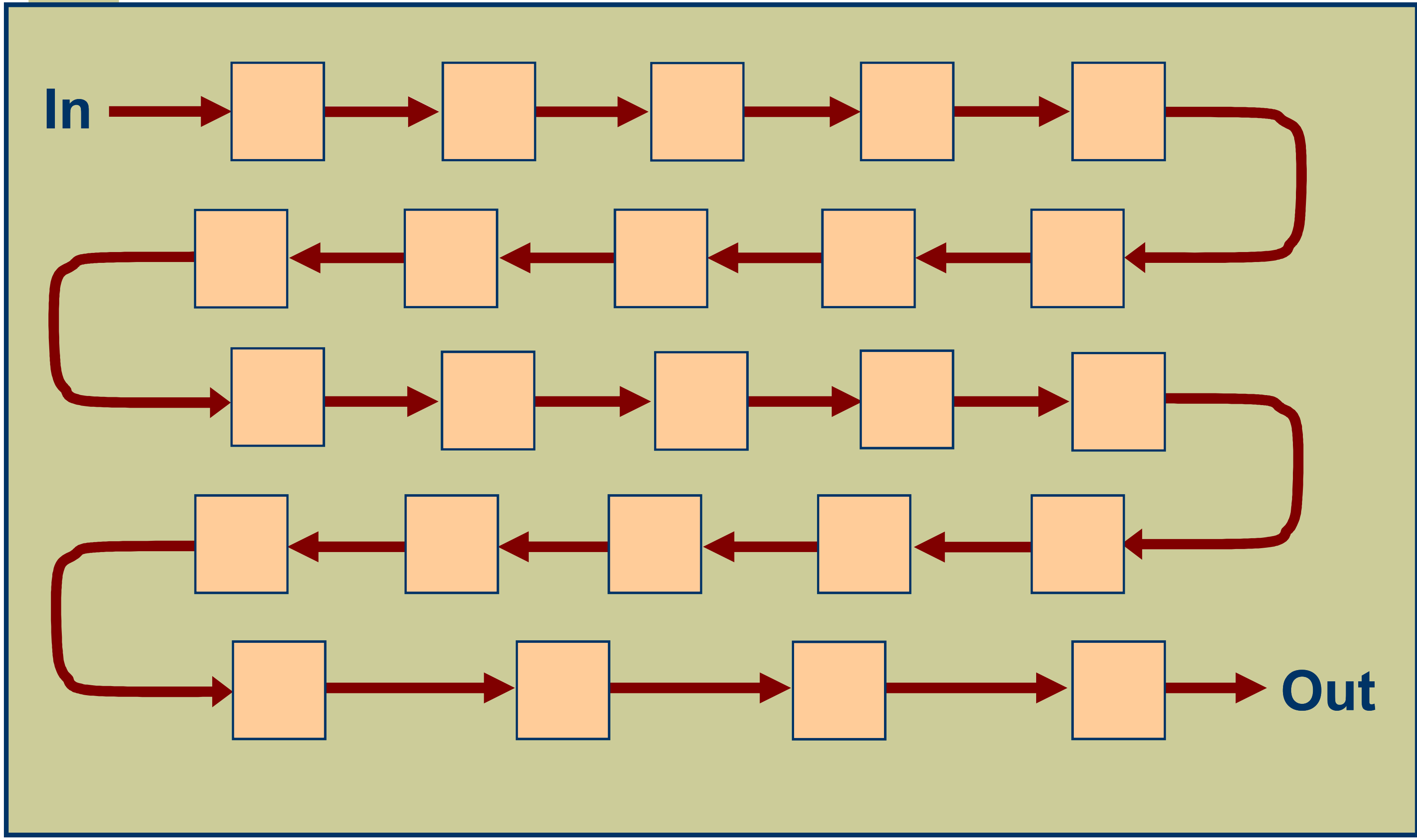
Process Layout in Services

Women's lingerie	Shoes	Housewares
Women's dresses	Cosmetics and jewelry	Children's department
Women's sportswear	Entry and display area	Men's department

Manufacturing Process Layout



A Product Layout



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

	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	Dynamic
Layout decision	Line balancing	Machine location
Goal	Equalize work at each station	Minimize material handling cost
Advantage	Efficiency	Flexibility

Fixed-Position Layouts

- Typical of projects in which product produced is too fragile, bulky, or heavy to move
- Equipment, workers, materials, other resources brought to the site
- Low equipment utilization
- Highly skilled labor
- Typically low fixed cost
- Often high variable

Designing Process Layouts

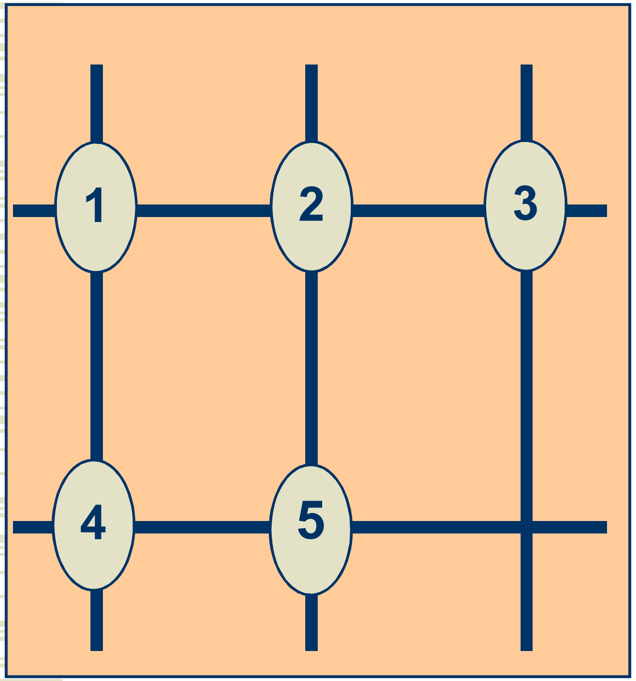
- Goal: minimize material handling costs
- Block Diagramming
  - minimize nonadjacent loads
  - use when quantitative data is available
- Relationship Diagramming
  - based on location preference between areas
  - use when quantitative data is not available

Block Diagramming

- Unit load
  - quantity in which material is normally moved
- Nonadjacent load
  - distance farther than the next block

- STEPS
  - create load summary chart
  - calculate composite (two way) movements
  - develop trial layouts minimizing number of nonadjacent loads

Block Diagramming: Example



Load Summary Chart

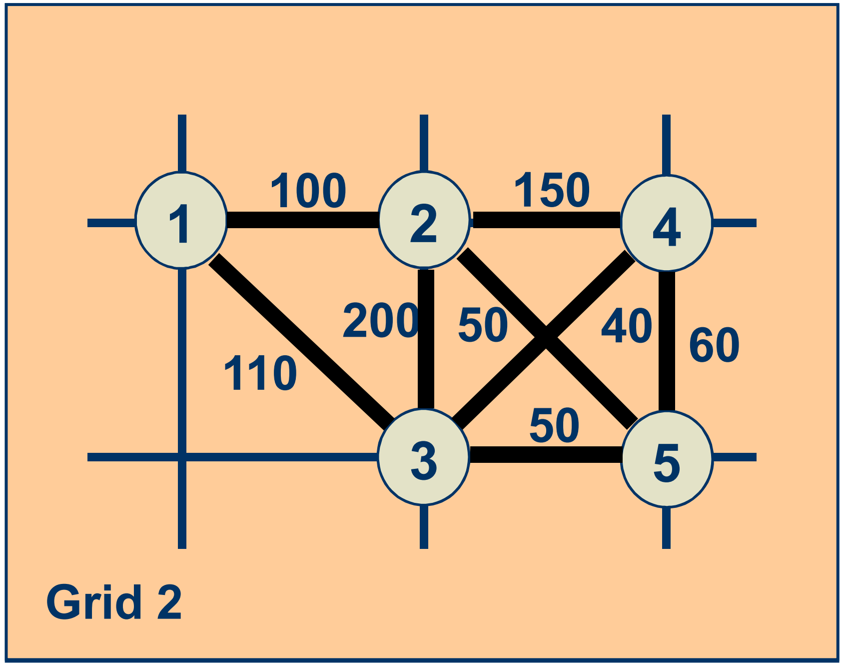
FROM/TO — **DEPARTMENT**

Department	*1*	*2*	*3*	*4*	*5*
1	—	100	50		
2		—	200	50	
3	60		—	40	50
4		100		—	60
5			50		—

Block Diagramming: Example (cont.)

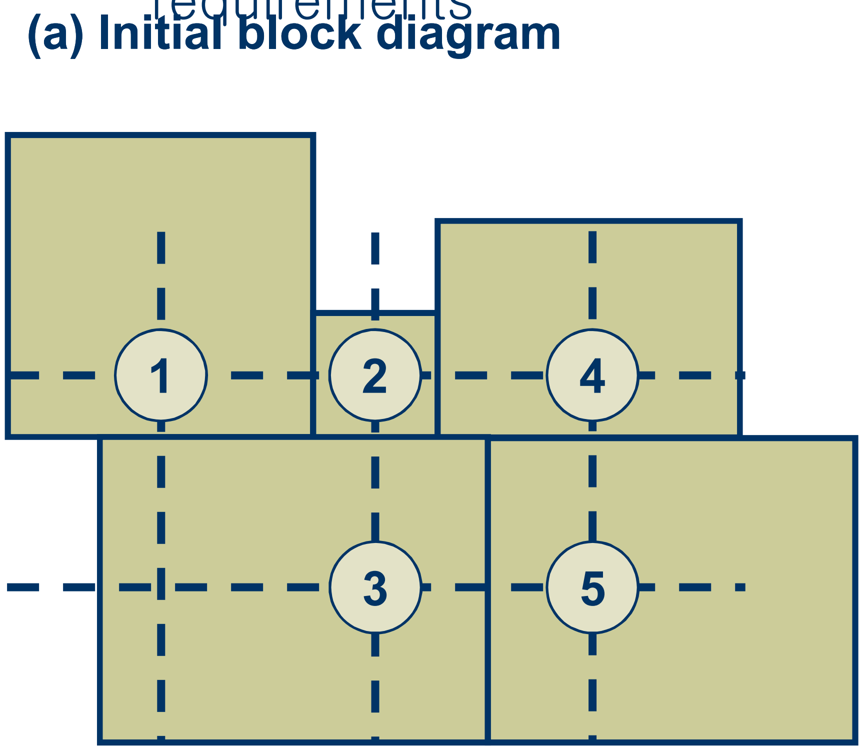
2 ↔ 3	200 loads
2 ↔ 4	150 loads
1 ↔ 3	110 loads
1 ↔ 2	100 loads
4 ↔ 5	60 loads
3 ↔ 5	50 loads
2 ↔ 5	50 loads
3 ↔ 4	40 loads
1 ↔ 4	0 loads
1 ↔ 5	0 loads

Nonadjacent Loads:
0



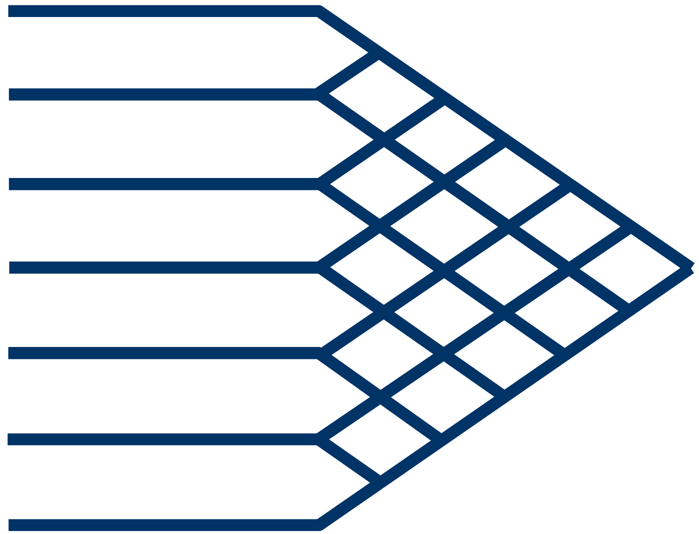
Block Diagramming: Example (cont.)

- Block Diagram
  - type of schematic layout diagram; includes space requirements

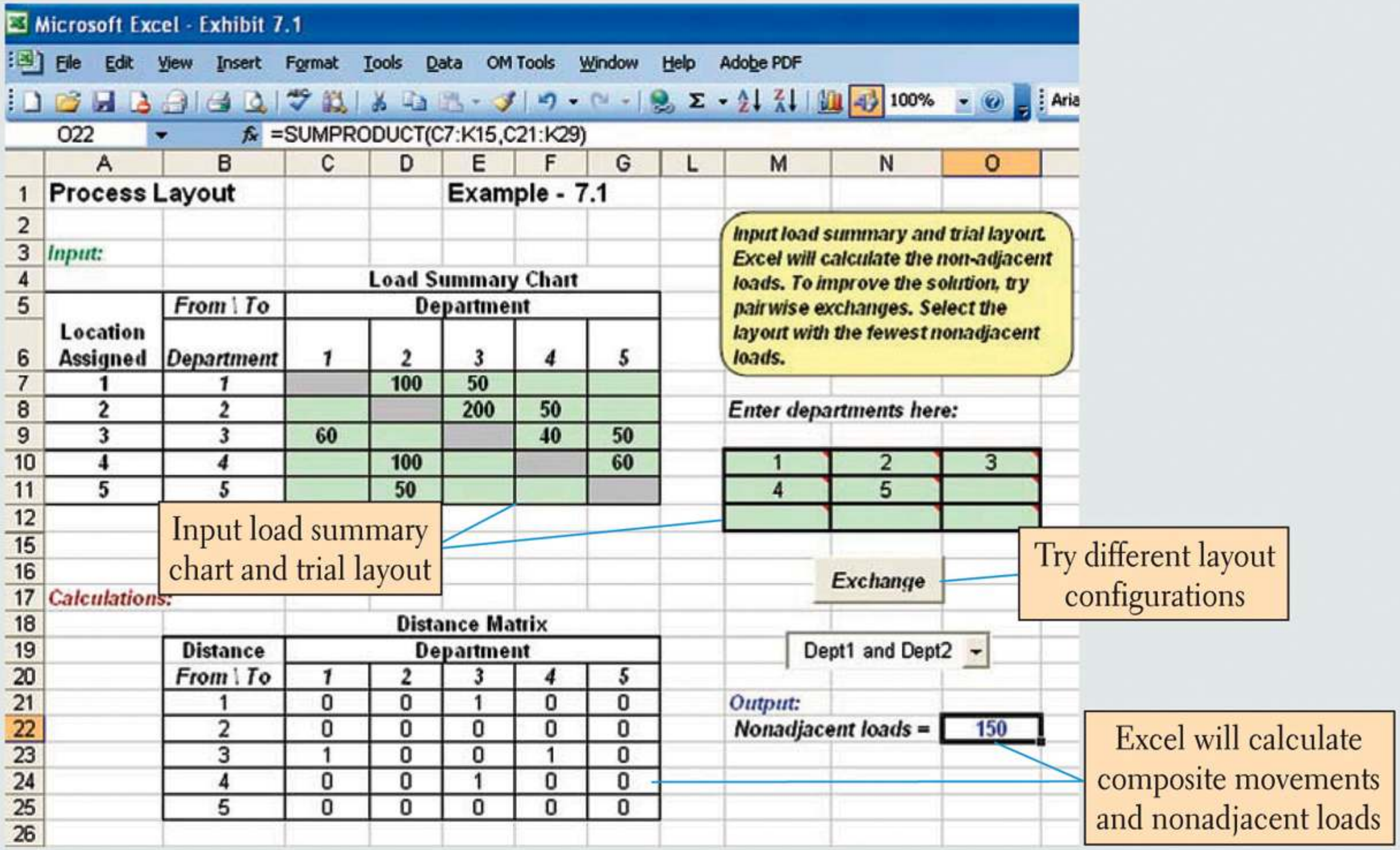


Relationship Diagramming

- Schematic diagram that uses weighted lines to denote location preference
- Muther's grid
  - format for displaying manager preferences for department locations

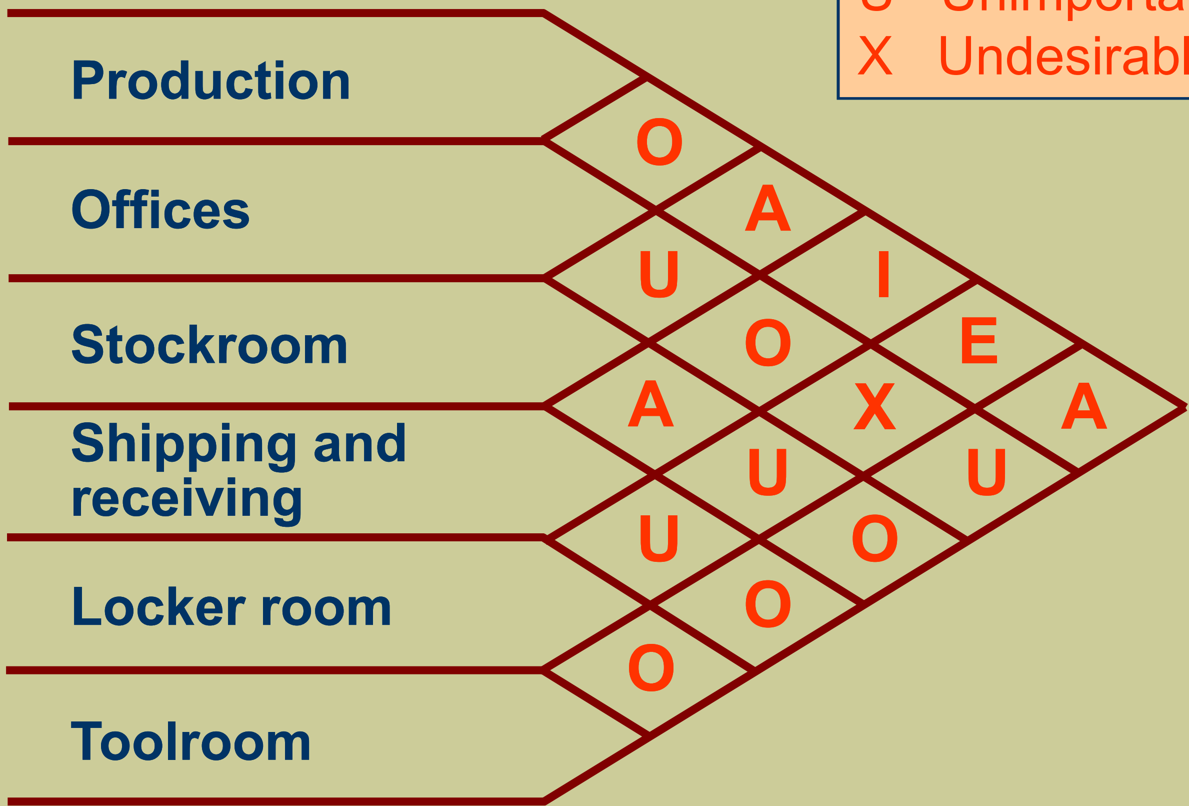


Relationship Diagramming: Excel



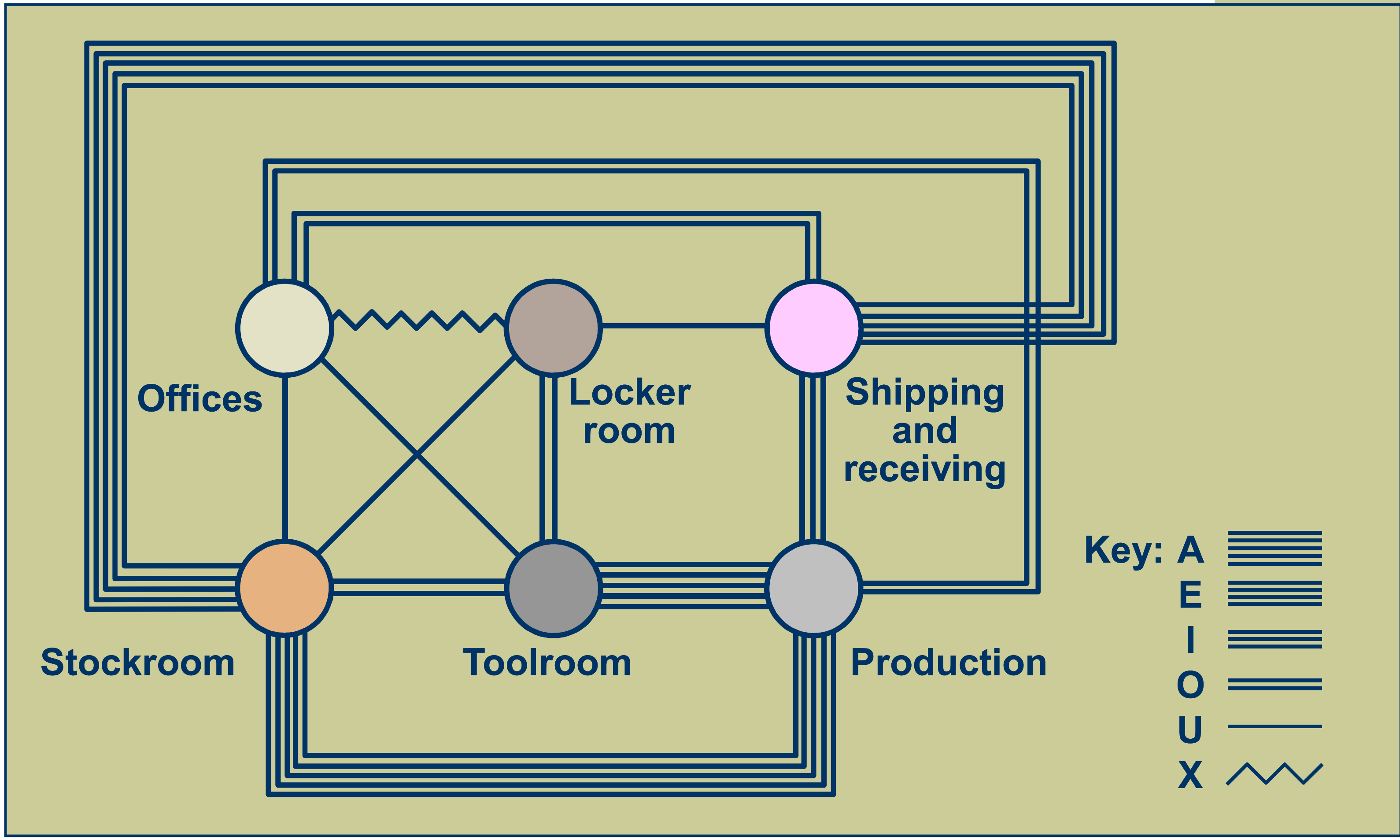
Relationship Diagramming:

A Absolutely necessary
E Especially important
I Important
O Okay
U Unimportant
X Undesirable



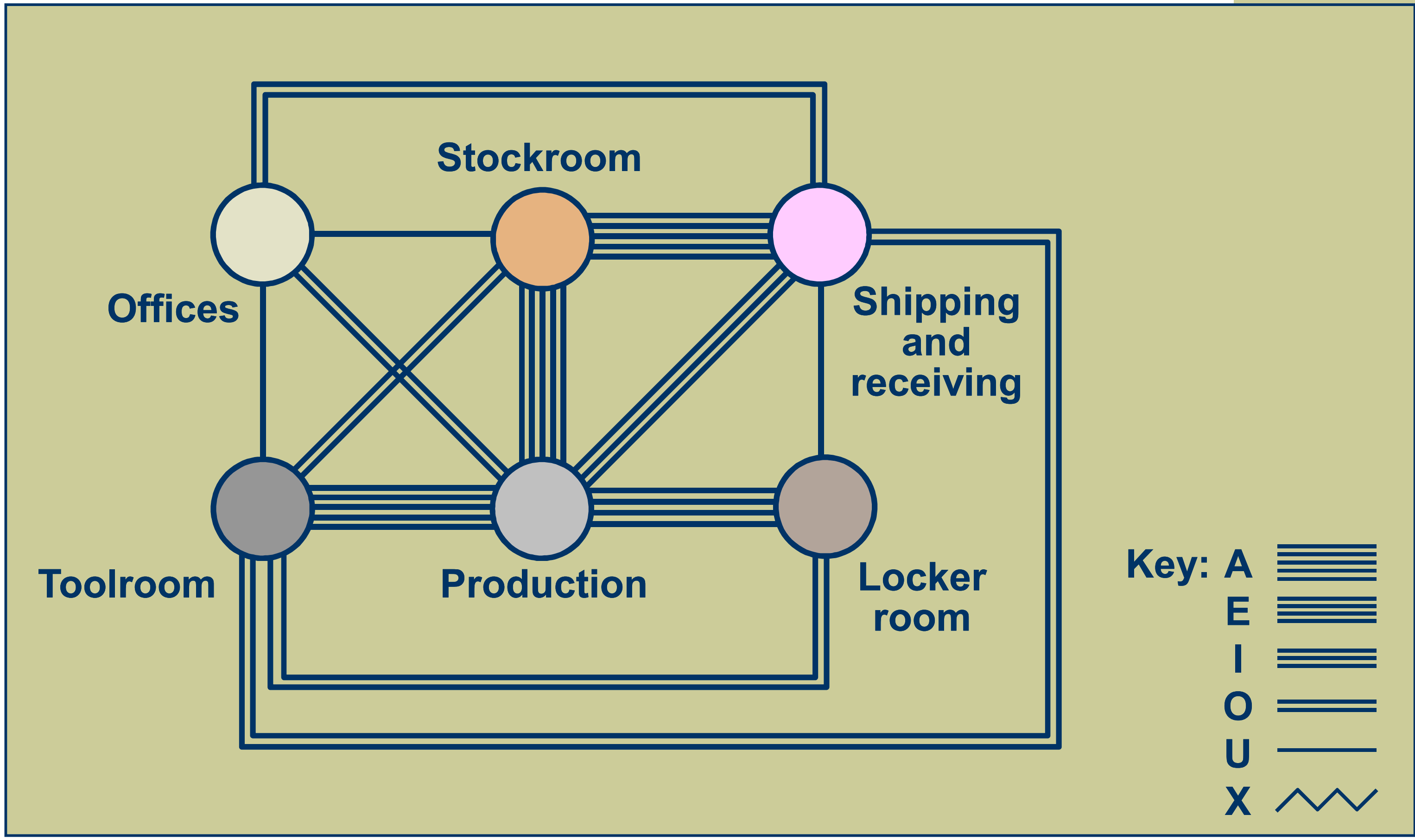
Relationship Diagrams: Example (cont.)

(a) Relationship diagram of original layout



Relationship Diagrams: Example (cont.)

(b) Relationship diagram of revised layout



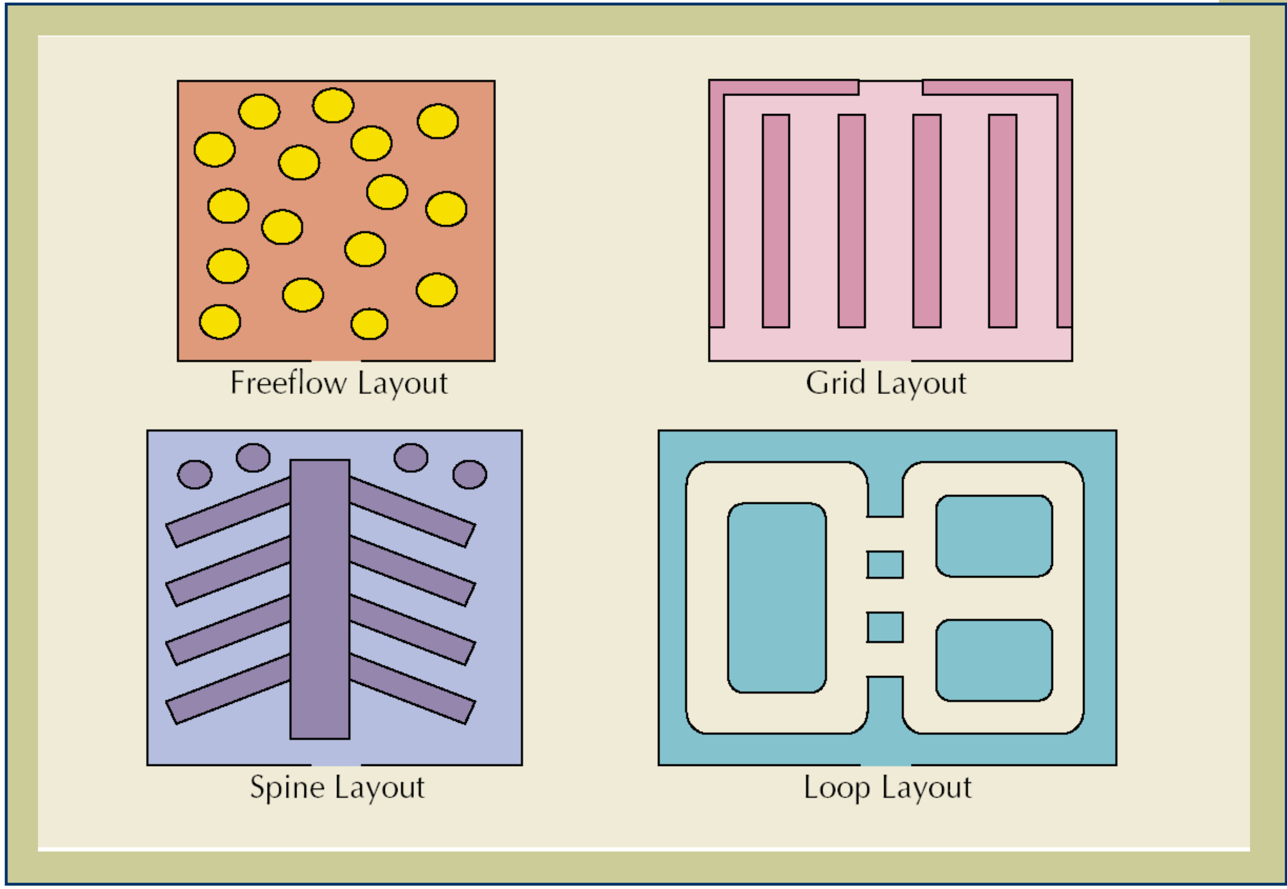
Computerized layout Solutions

- CRAFT
  - Computerized Relative Allocation of Facilities Technique
- CORELAP
  - Computerized Relationship Layout Planning
- PROMODEL and EXTEND
  - visual feedback
  - allow user to quickly test a variety of scenarios
- Three-D modeling and CAD
  - integrated layout analysis
  - available in VisFactory and similar software

Designing Service Layouts

- Must be both attractive and functional
- Types
  - Free flow layouts
    - encourage browsing, increase impulse purchasing, are flexible and visually appealing
  - Grid layouts
    - encourage customer familiarity, are low cost, easy to clean and secure, and good for repeat customers
  - Loop and Spine layouts
    - both increase customer sightlines and exposure to products, while encouraging customer to circulate through the entire store

Types of Store Layouts



Designing Product Layouts

- Objective
  - Balance the assembly line
- Line balancing
  - tries to equalize the amount of work at each workstation
- Precedence requirements
  - physical restrictions on the order in which operations are performed
- Cycle time
  - maximum amount of time a product is allowed to spend at each workstation

Cycle Time Example

$$C_d = \frac{\text{production time available}}{\text{desired units of output}}$$

$$C_d = \frac{(8 \text{ hours x } 60 \text{ minutes / hour})}{(120 \text{ units})}$$

$$C_d = \frac{480}{120} = 4 \text{ minutes}$$

Flow Time vs Cycle Time

- Cycle time = max time spent at any station
- Flow time = time to complete all stations

Flow time = 4 + 4 + 4 = 12 minutes
Cycle time = max (4, 4, 4) = 4 minutes

Efficiency of Line and Balance Delay

Efficiency

$$E = \frac{\sum_{i=1}^{i} t_i}{nC_a}$$

Minimum number of workstations

$$N = \frac{\sum_{i=1}^{i} t_i}{C_d}$$

where

t_i = completion time for element i
j = number of work elements
n = actual number of workstations
C_a = actual cycle time
C_d = desired cycle time

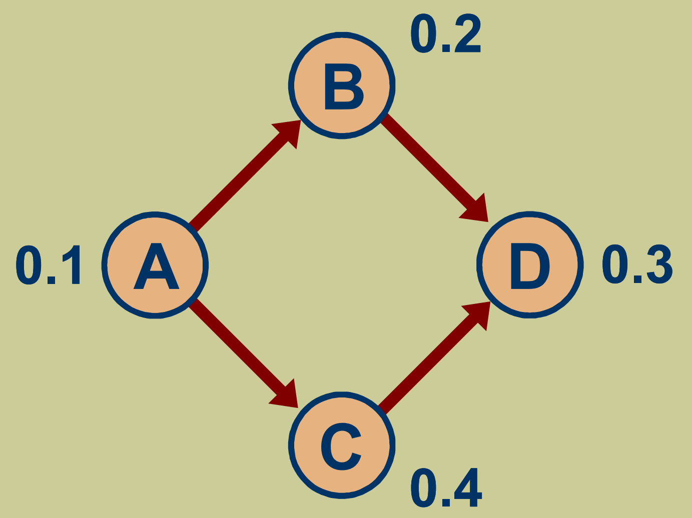
- Balance delay
  - total idle time of line
  - calculated as (1 − efficiency)

Line Balancing Procedure

1. Draw and label a precedence diagram
2. Calculate desired cycle time required for line
3. Calculate theoretical minimum number of workstations
4. Group elements into workstations, recognizing cycle time and precedence constraints
5. Calculate efficiency of line
6. Determine if theoretical minimum number of workstations or an acceptable efficiency level has been reached. If not, go back to step 4.

Line Balancing: Example

	WORK ELEMENT	PRECEDENCE	TIME (MIN)
A	Press out sheet of fruit	—	0.1
B	Cut into strips	A	0.2
C	Outline fun shapes	A	0.4
D	Roll up and package	B, C	0.3



Line Balancing: Example (cont.)

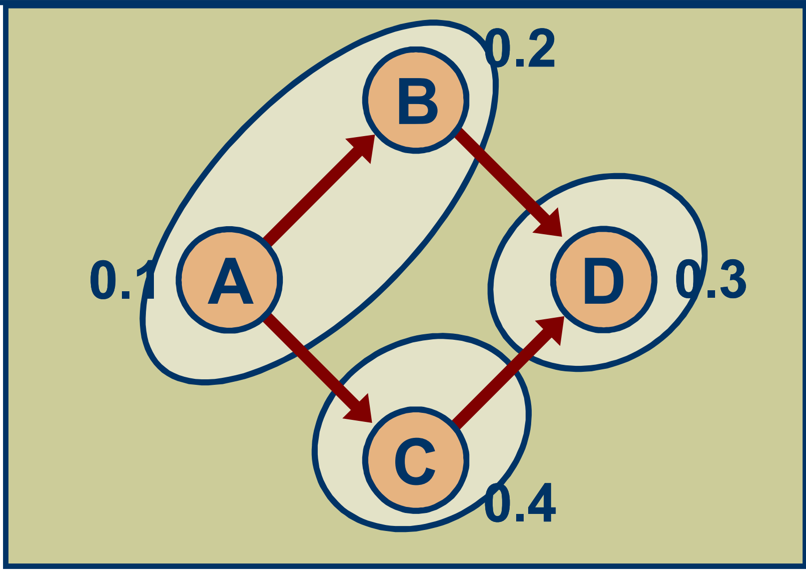
	WORK ELEMENT	PRECEDENCE	TIME (MIN)
A	Press out sheet of fruit	—	0.1
B	Cut into strips	A	0.2
C	Outline fun shapes	A	0.4
D	Roll up and package	B, C	0.3

$$C_d = \frac{\text{40 hours x 60 minutes / hour}}{\text{6,000 units}} = \frac{2400}{6000} = 0.4 \text{ minute}$$

$$N = \frac{0.1 + 0.2 + 0.3 + 0.4}{0.4} = \frac{1.0}{0.4} = 2.5 \rightarrow 3 \text{ workstations}$$

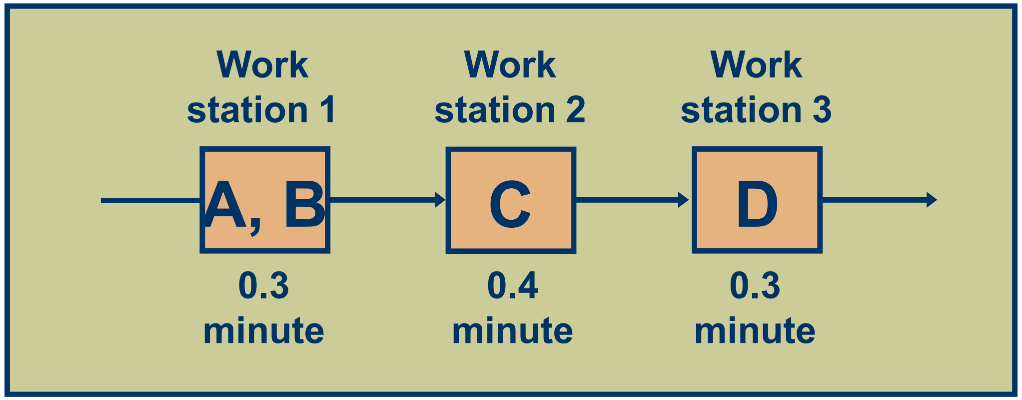
Line Balancing: Example (cont.)

WORKSTATION	ELEMENT	REMAINING TIME	REMAINING ELEMENTS
1	A	0.3	B, C
	B	0.1	C, D
2	C	0.0	D
3	D	0.1	none



$C_d = 0.4$
$N = 2.5$

Line Balancing: Example (cont.)



C_d = 0.4
N = 2.5

$$E = \frac{0.1 + 0.2 + 0.3 + 0.4}{3(0.4)} = \frac{1.0}{1.2} = 0.833 = 83.3\%$$

Computerized Line Balancing

- Use heuristics to assign tasks to workstations
  - Longest operation time
  - Shortest operation time
  - Most number of following tasks
  - Least number of following tasks
  - Ranked positional weight

Hybrid Layouts

- Cellular layouts
  - group dissimilar machines into work centers (called cells) that process families of parts with similar shapes or processing requirements
- Production flow analysis (PFA)
  - reorders part routing matrices to identify families of parts with similar processing requirements
- Flexible manufacturing system
  - automated machining and material handling systems which can produce an enormous variety of items
- Mixed-model assembly line
  - processes more than one product model in one line

Cellular Layouts

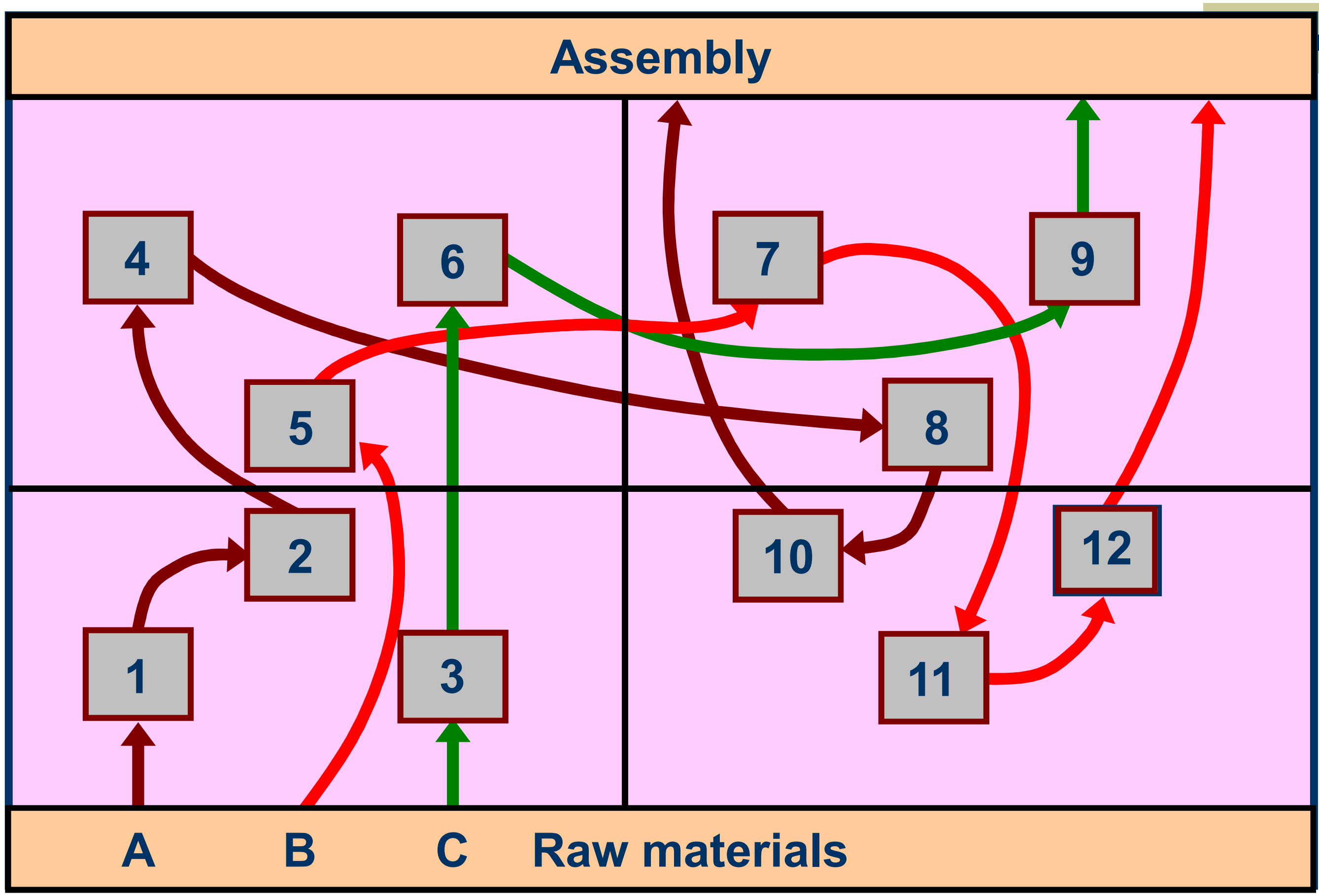
1. Identify families of parts with similar flow paths
2. Group machines into cells based on part families
3. Arrange cells so material movement is minimized
4. Locate large shared machines at point of use

Parts Families

A family of similar parts

A family of related grocery items

Original Process Layout

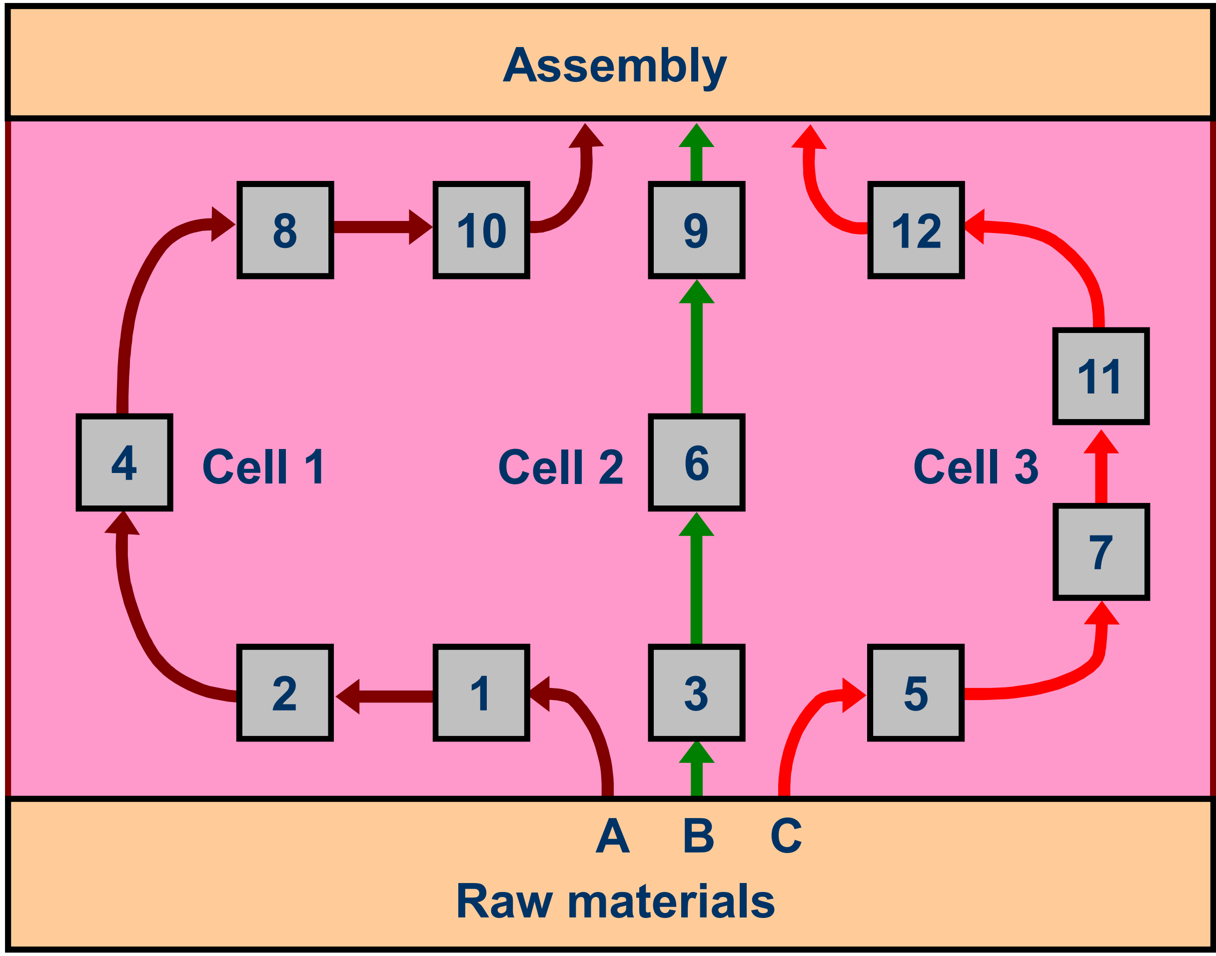


Part Routing Matrix

	Machines											
Parts	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
A	x	x		x				x		x		
B					x		x				x	x
C			x			x			x			
D	x	x		x				x		x		
E				x	x							x
F	x			x				x				
G			x			x			x			x
H							x				x	x

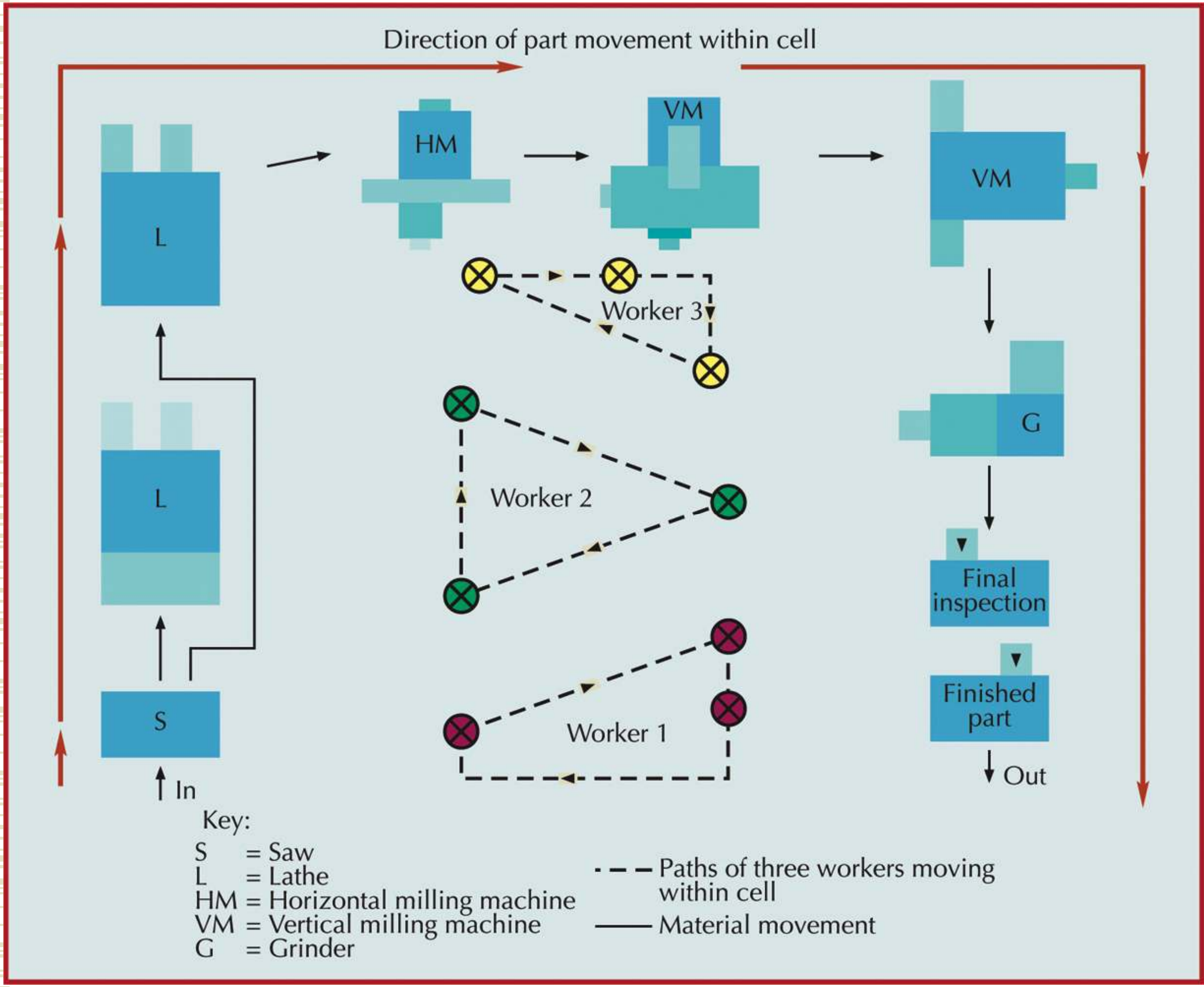
Figure 5.8

Revised Cellular Layout



Reordered Routing Matrix

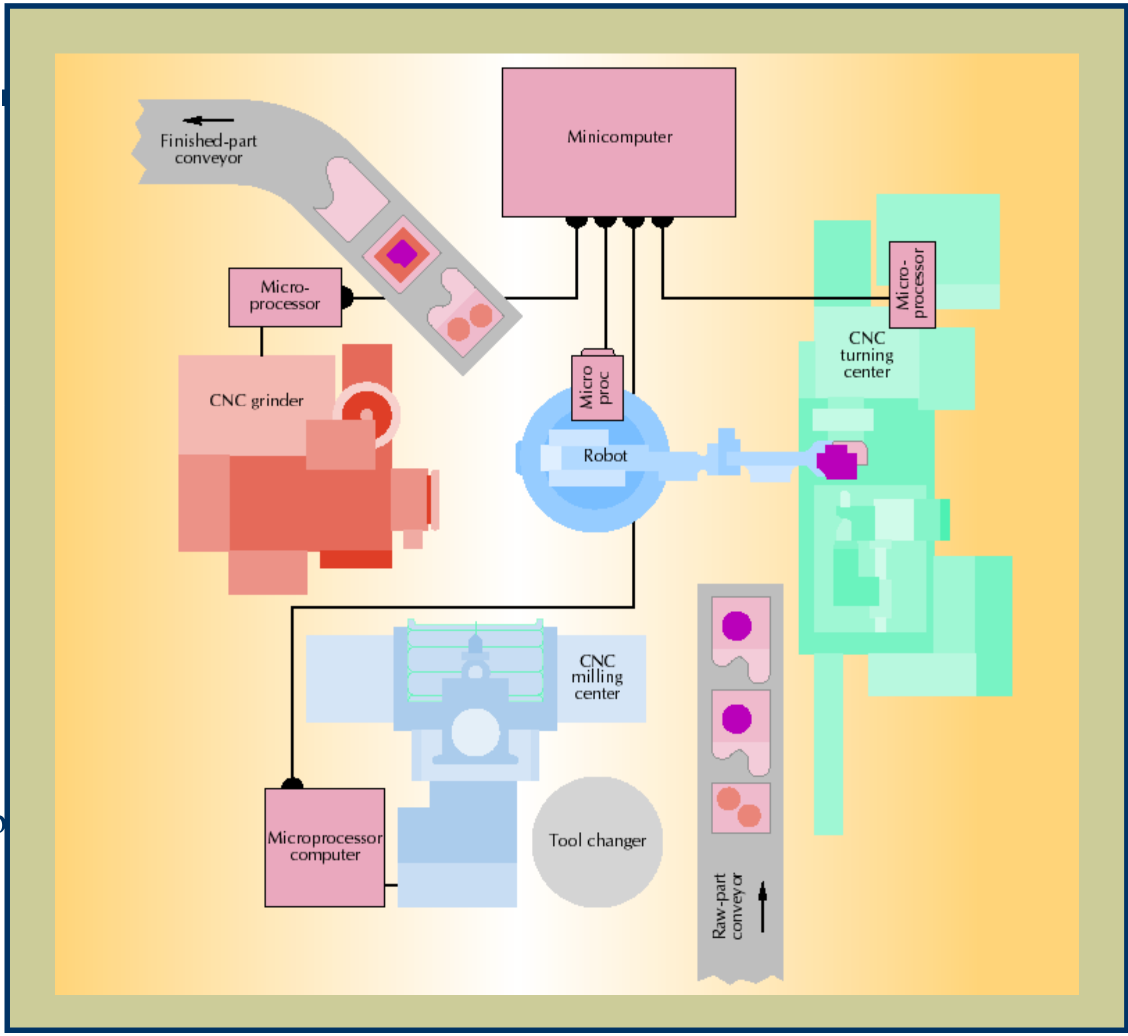
Parts	Machines 1	2	4	8	10	3	6	9	5	7	11	12
A	x	x	x	x	x							
D	x	x	x	x	x							
F	x		x	x								
C						x	x	x				
G						x	x	x				x
B									x	x	x	x
H										x	x	x
E							x		x			x


Direction of part movement within cell
HM
VM
VM
L
L
S
G
Worker 3
Worker 2
Worker 1
Final inspection
Finished part
In
Out
Key:
S = Saw
L = Lathe
HM = Horizontal milling machine
VM = Vertical milling machine
G = Grinder
Paths of three workers moving within cell
Material movement

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*
  - *Inadequate part families*
  - *Poorly balanced cells*
  - *Expanded training and scheduling of workers*
  - *Increased capital investment*

Automated Manufacturing Cell

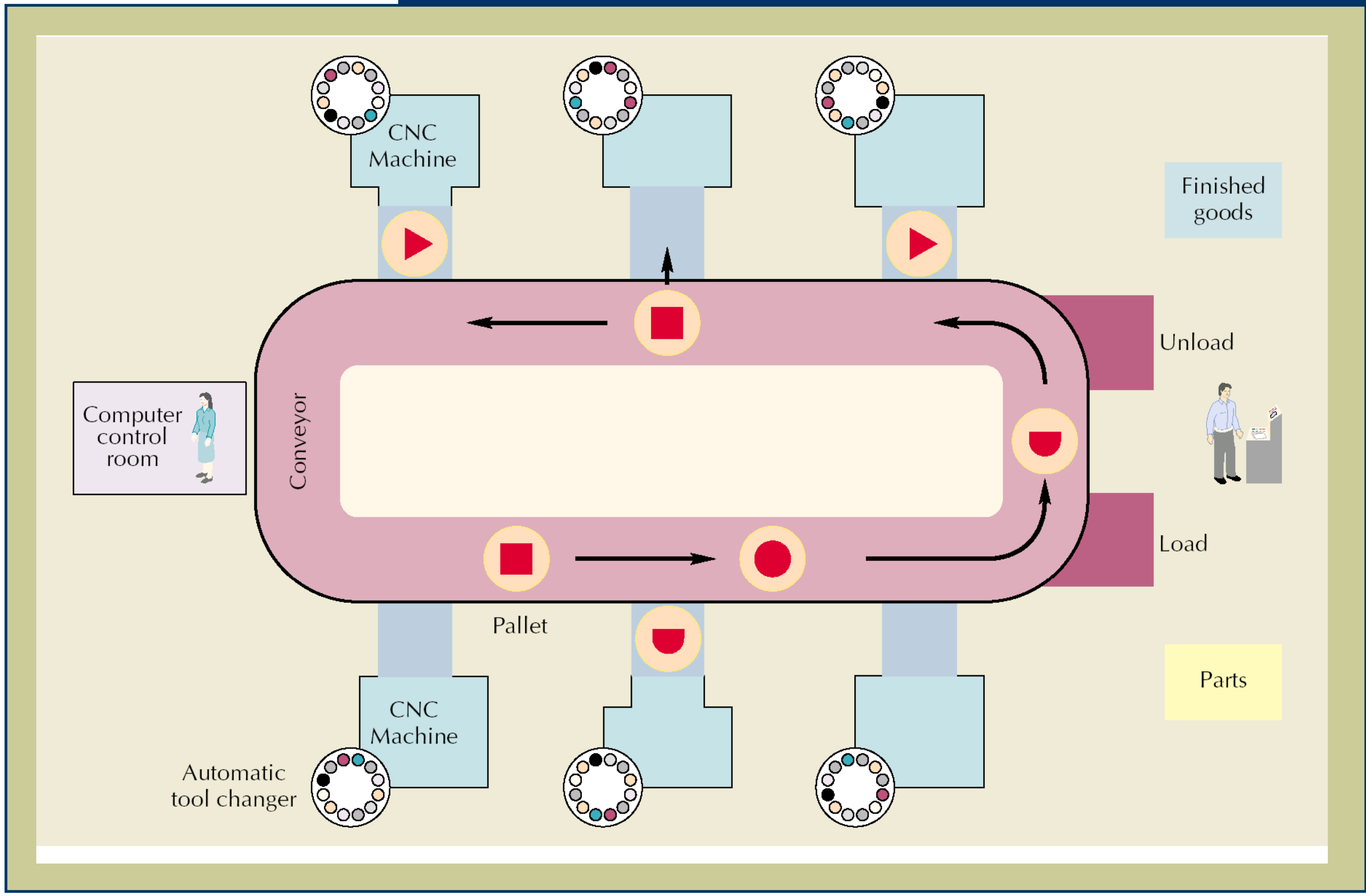


Source: J. T. Black, "Cellular Manufacturing Systems Reduce Setup Time, Make Small Lot Production Economical." *Industrial Engineering* (November 1983)

Flexible Manufacturing Systems (FMS)

- FMS consists of numerous programmable machine tools connected by an automated material handling system and controlled by a common computer network
- FMS combines flexibility with efficiency
- FMS layouts differ based on
  - variety of parts that the system can process
  - size of parts processed
  - average processing time required for part completion

Full-Blown FMS

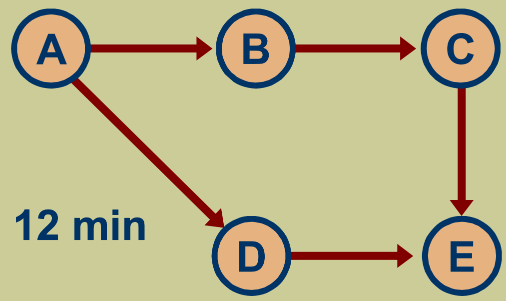


Mixed Model Assembly Lines

- Produce multiple models in any order on one assembly line
- Issues in mixed model lines
  - Line balancing
  - U-shaped lines
  - Flexible workforce
  - Model sequencing

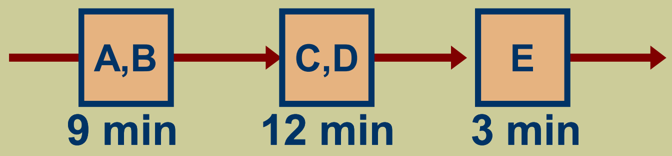
Balancing U-Shaped Lines

Precedence diagram:



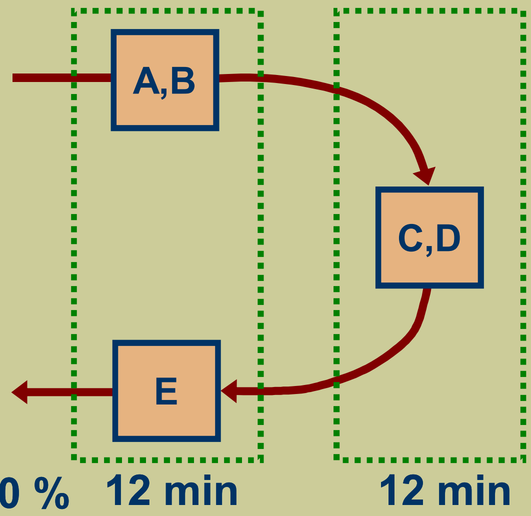
Cycle time = 12 min

(a) Balanced for a straight line



$$\text{Efficiency} = \frac{24}{3(12)} = \frac{24}{36} = .6666 = 66.7\ \%$$

(b) Balanced for a U-shaped line



$$\text{Efficiency} = \frac{24}{2(12)} = \frac{24}{24} = 100\ \%$$