Facilities Planning

LAYOUT (Part 2)

ASSEMBLY LINE LAYOUT

The Boeing 737, the world's most popular commercial airplane is produced on a moving production line, traveling at two inches a minute through the final assembly process. The moving line, one of several lean manufacturing innovations at the Renton, Washington facility, has enhanced quality, reduced flow time, slashed inventory levels, and cut space requirements. Final assembly is only 11 days and inventory is down over 55 percent.

Conventional approach for developing product layout

- Product layouts are suitable for mass production of discrete items
- Products layout are used to achieve smooth flow of large volume of highly standardised products that require repetitive processing operations
- The main issue in design of product layout is line balancing
- The process of deciding how to assign tasks to work stations on the line is referred to as line balancing
- The objective of line balancing is to obtain task groupings that represent approximately equal time requirement.

Conventional approach for developing product layout(cont)

- Perfect balance would lead to smooth flow of work
- It is difficult to achieve perfect balancing as a result of inability to obtain task groupings that have same durations
- The cycle time which is the amount of time each work station has to complete its set of task before the product moves to the next station, determines the output rate per line

Example 3
Developing a precedence diagram for an assembly line

We want to develop a precedence diagram for an electrostatic copier that requires a total assembly t of 66 minutes. Table 9.3 and Figure 9.12 give the tasks, assembly times, and sequence requirements the copier.

TABLE 9.3 ■ Precedence Data

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.

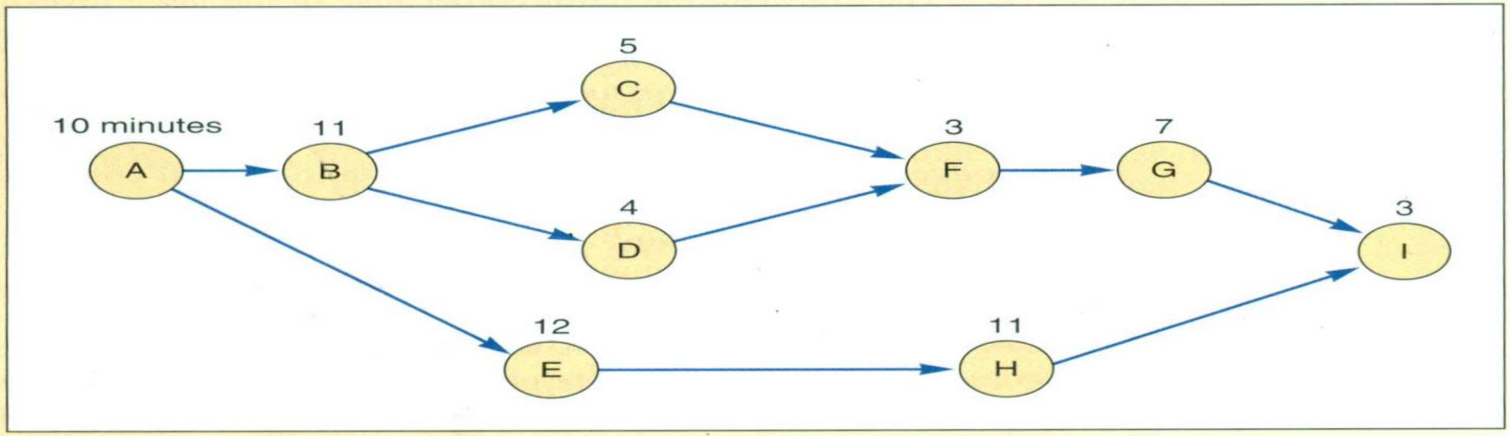


FIGURE 9.12 ■ Precedence Diagram

LINE BALANCING

- Once we have constructed a precedence chart summarizing the sequences and performance
times,
- we turn to the job of grouping tasks into job stations so that we can meet the specified production rate.
- This process involves three steps:
- 1. Take the units required (demand or production rate) per day and divide it into the productive time available per day (in minutes or seconds).

Cycle time

- This operation gives us what is called the **cycle time**-namely, the maximum time allowed at each workstation if the production rate is to be achieved:
- **Cycle time**
- The maximum time that the product is allowed at each workstation.

Cycle time

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

Theoretical Minimum Number of Workstations

- Calculate the theoretical minimum number of workstations. This is the total task-duration time (the time it takes to make the product) divided by the cycle time.
- Fractions are rounded to the next higher whole number:
- Some tasks simply cannot be grouped together in one workstation. There may be a variety of physical reasons for this.

theoretical minimum number of workstations

$$\text{Minimum number of workstations} = \frac{\sum_{i=1}^{n} \text{Time for task } i}{\text{Cycle time}}$$

LINE BALANCING

- Balance the line by assigning specific assembly tasks to each workstation.
- An efficient balance is one that will
  - complete the required assembly,
  - follow the specified sequence, and
  - keep the idle time at each workstation to a minimum.

LINE BALANCING

- A formal procedure for doing this is the following:
- a. Identify a master list of tasks.
- b. Eliminate those tasks that have been assigned.
- c. Eliminate those tasks whose precedence relationship has not been satisfied.
- d. Eliminate those tasks for which inadequate time is available at the workstation.

LINE BALANCING

- e. Use one of the line-balancing "heuristics"

The five choices are:
  - (1) longest task time,
  - (2) most following tasks,
  - (3) ranked positional weight,
  - (4) shortest task time, and
  - (5) least number of following tasks.
- You may wish to test several of these heuristics to see which generates the "best" solution-that is, the smallest number of workstations and highest efficiency.
- Remember, however, that although heuristics provide solutions, they do not guarantee an optimal solution.

LINE BALANCING HEURISTICS

- Layout Heuristics **that** May Be Used to Assign Tasks to Work Stations in Assembly-Line Balancing

1. L*ongest task (operation) time*	**From the available tasks, choose the task with the largest (longest) time.**
2. Most following tasks	From the available tasks, choose the task with the largest number of following tasks.
3. *Ranked positional weight*	From the available tasks, choose the task for which the sum of the times for each following task is longest. (In Example 3 we will see that the ranked positional weight of task C = S(C) + 3(F) + 7(G) + 3(1) = 18, whereas the ranked positional weight of task D = 4(D) + 3(F) + 7(G) + 3(1) = 17; therefore, C would be chosen first.)
4. Shortest task (operations) time	From the available tasks, choose the task with the shortest task time
5. Least number of following tasks	From the available tasks, choose the task with the least number of subsequent tasks

EXAMPLE

On the basis of the precedence diagram and activity times given in Example 3, the firm determines that there are 480 productive minutes of work available per day. Furthermore, the production schedule requires that 40 units be completed as output from the assembly line each day. Thus:

$$\text{Cycle time (in minutes)} = \frac{480 \text{ minutes}}{40 \text{ units}}$$

$$= 12 \text{ minutes/unit}$$

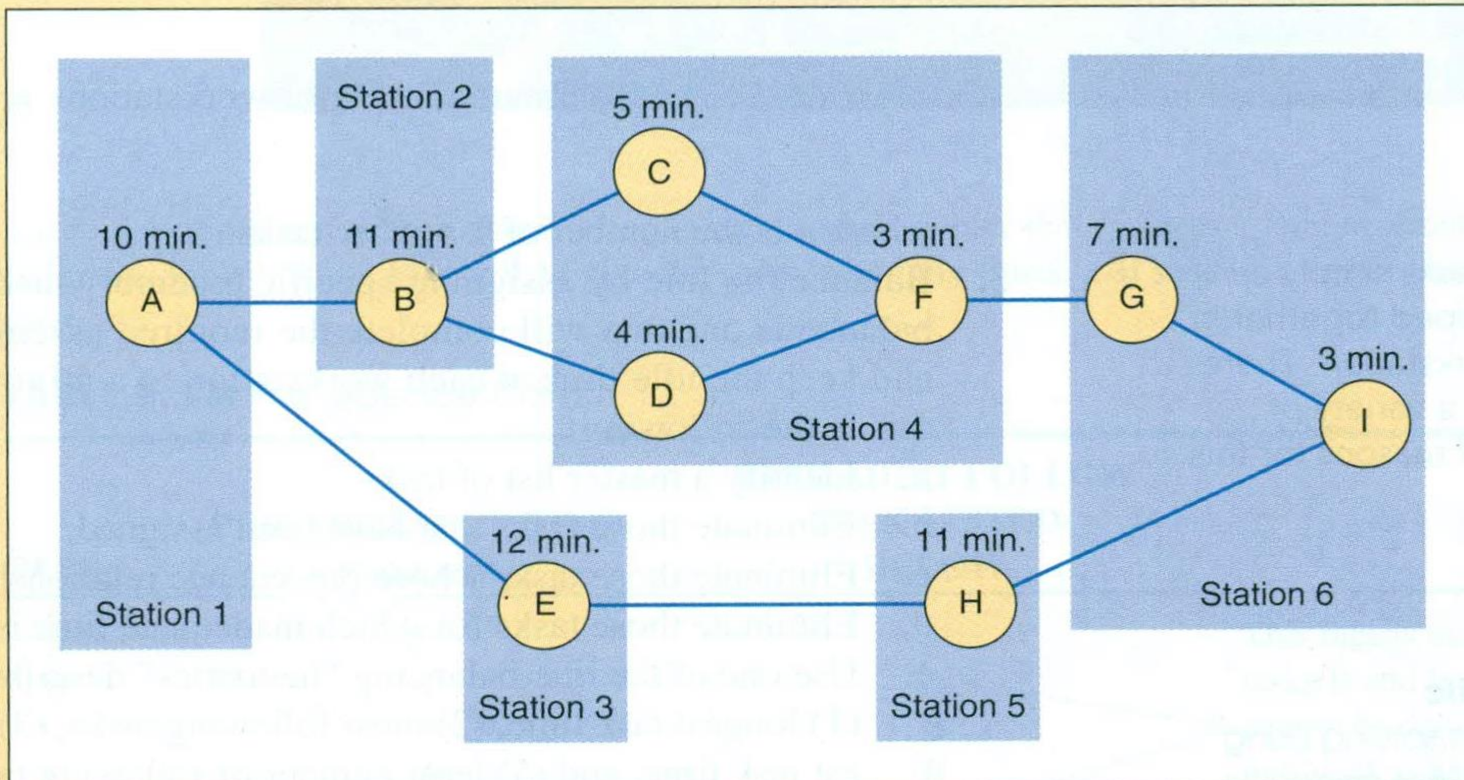
$$\text{Minimum number of workstations} = \frac{\text{Total task time}}{\text{Cycle time}} = \frac{66}{12}$$

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

ASSIGNING TASKS TO WORKSTATIONS

Use the *most following tasks* heuristic to assign jobs to workstations.

Figure 9.13 shows one solution that does not violate the sequence requirements and that groups tasks into six stations. To obtain this solution, activities with the most following tasks were moved into workstations to use as much of the available cycle time of 12 minutes as possible. The first workstation consumes 10 minutes and has an idle time of 2 minutes.



The second workstation uses 11 minutes, and the third consumes the full 12 minutes. The fourth workstation groups three small tasks and balances perfectly at 12 minutes. The fifth has 1 minute of idle time, and the sixth (consisting of tasks G and I) has 2 minutes of idle time per cycle. Total idle time for this solution is 6 minutes per cycle.

EFFICIENCY OF LINE CALCULATIONS

We can compute the efficiency of a line balance by dividing the total task time by the product of the number of workstations required times the assigned (actual) cycle time of the longest workstation.

$$\text{Efficiency} = \frac{\sum \text{Task times}}{(\text{Actual number of workstations}) \times (\text{Largest assigned cycle time})} \tag{9-6}$$

Operations managers compare different levels of efficiency for various numbers of workstations. In this way, the firm can determine the sensitivity of the line to changes in the production rate and workstation assignments.

EFFICIENCY OF LINE CALCULATIONS

We can calculate the balance efficiency for Example 4 as follows:

$$\text{Efficiency} = \frac{66 \text{ minutes}}{(6 \text{ stations}) \times (12 \text{ minutes})} = \frac{66}{72} = 91.7\%$$

Note that opening a seventh workstation, for whatever reason, would decrease the efficiency of the balance to 78.6% (assuming that at least one of the workstations still required 12 minutes):

$$\text{Efficiency} = \frac{66 \text{ minutes}}{(7 \text{ stations}) \times (12 \text{ minutes})} = 78.6\%$$

PROCESS LAYOUT

Walters Company management wants to arrange the six departments of its factory in a way that will minimize interdepartmental material handling costs. They make an initial assumption (to simplify the problem) that each department is 20 × 20 feet and that the building is 60 feet long and 40 feet wide. The process layout procedure that they follow involves six steps:

Step 1: *Construct a "from-to matrix"* showing the flow of parts or materials from department to department (Figure 9.4).

Step 2: *Determine the space requirements* for each department. (Figure 9.5 shows available plant space.)

Step 3: *Develop an initial schematic diagram* showing the sequence of departments through which parts must move. Try to place departments with a heavy flow of materials or parts next to one another. (See Figure 9.6 on page 352.)

FROM – TO CHART

Department						
	Number of loads per week					
	Assembly (1)	Painting (2)	Machine Shop (3)	Receiving (4)	Shipping (5)	Testing (6)
Assembly (1)		50	100	0	0	20
Painting (2)			30	50	10	0
Machine Shop (3)				20	0	100
Receiving (4)					50	0
Shipping (5)						0
Testing (6)						

POSSIBLE LAYOUT DIMENTION

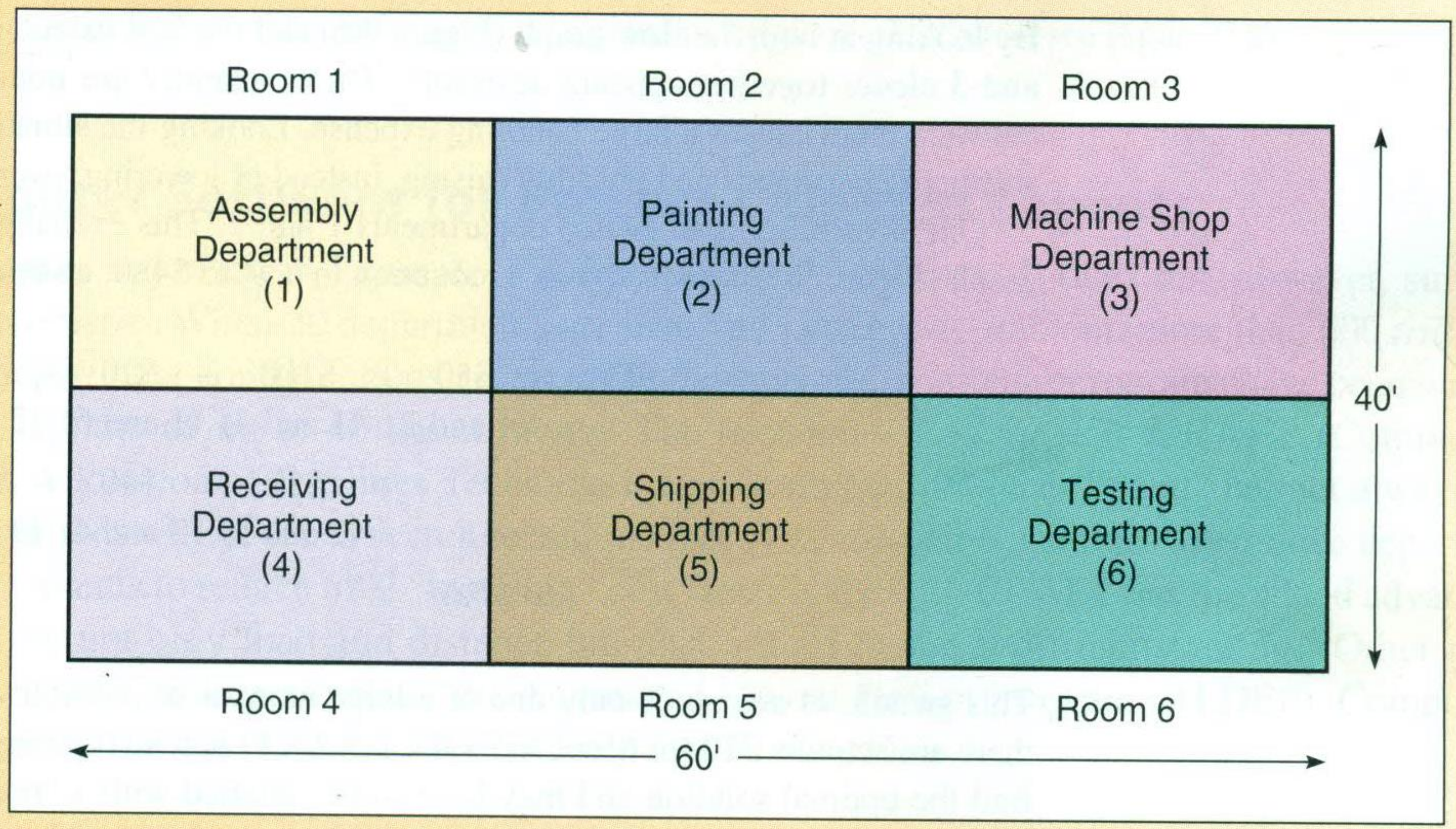


FIGURE 9.5 ■ Building Dimensions and a Possible Department Layout

Step 4: *Determine* the cost *of this layout by using the material handling cost equation:*

COST OF LAYOUT

Step 4: *Determine* the cost *of this layout by using the material handling cost equation:*

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

For this problem, Walters Company assumes that a forklift carries all interdepartmental loads. The cost of moving one load between adjacent departments is estimated to be \$1. Moving a load between nonadjacent departments costs \$2. Looking at Figure 9.4, we thus see that the handling cost between departments 1 and 2 is \$50 (\$1 × 50 loads), \$200 between departments 1 and 3 (\$2 × 100 loads), \$40 between departments 1 and 6 (\$2 × 20 loads), and so on. Rooms that are diagonal to one another, such as 2 and 4, are treated as adjacent. The total cost for the layout shown in Figure 9.6 is:

$$\begin{aligned}\text{Cost} = \; & \underset{(1\text{ and }2)}{\$50} + \underset{(1\text{ and }3)}{\$200} + \underset{(1\text{ and }6)}{\$40} + \underset{(2\text{ and }3)}{\$30} + \underset{(2\text{ and }4)}{\$50} \\ & + \underset{(2\text{ and }5)}{\$10} + \underset{(3\text{ and }4)}{\$40} + \underset{(3\text{ and }6)}{\$100} + \underset{(4\text{ and }5)}{\$50} \\ = \; & \$570\end{aligned}$$

INTERDEPARTMENTAL FLOW GRAPH

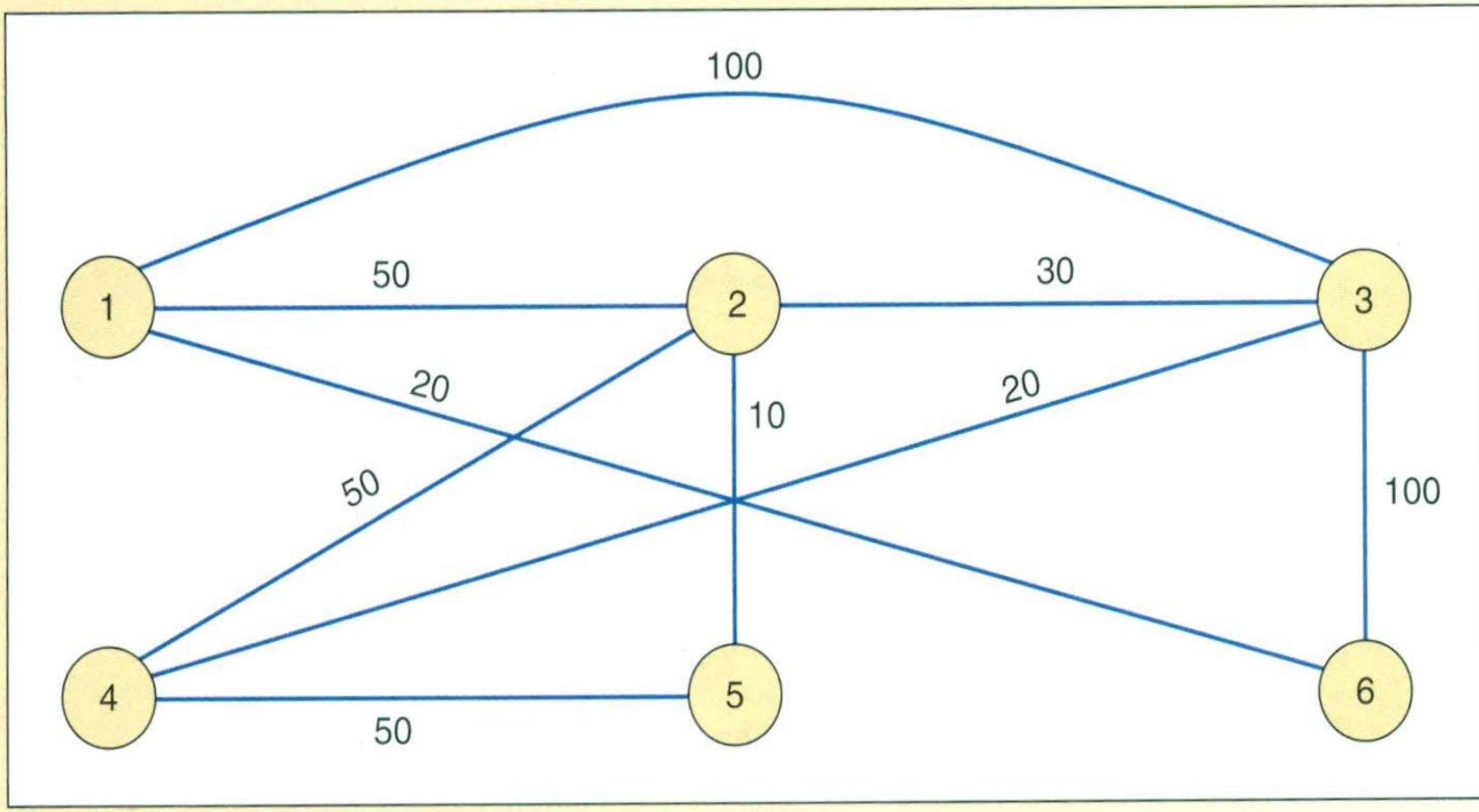


FIGURE 9.6 ■ Interdepartmental Flow Graph Showing Number of Weekly Loads

Step 5: By trial and error (or by a more sophisticated computer program approach that we discuss shortly), *try to improve the layout* pictured in Figure 9.5 to establish a reasonably good arrangement of departments.

By looking at both the flow graph (Figure 9.6) and the cost calculations, we see that placing departments 1 and 3 closer together appears desirable. They currently are nonadjacent, and the high volume of flow between them causes a large handling expense. Looking the situation over, we need to check the effect of shifting departments and possibly raising, instead of lowering, overall costs.

One possibility is to switch departments 1 and 2. This exchange produces a second departmental flow graph (Figure 9.7), which shows a reduction in cost to \$480, a savings in material handling of \$90.

$$\begin{aligned} \text{Cost} = {} & \underset{(1\text{ and }2)}{\$50} + \underset{(1\text{ and }3)}{\$100} + \underset{(1\text{ and }6)}{\$20} + \underset{(2\text{ and }3)}{\$60} + \underset{(2\text{ and }4)}{\$50} \\ & + \underset{(2\text{ and }5)}{\$10} + \underset{(3\text{ and }4)}{\$40} + \underset{(3\text{ and }6)}{\$100} + \underset{(4\text{ and }5)}{\$50} \\ = {} & \$480 \end{aligned}$$

This switch, of course, is only one of a large number of possible changes. For a six-department problem, there are actually 720 (or $6! = 6 \times 5 \times 4 \times 3 \times 2 \times 1$) potential arrangements! In layout problems, we seldom find the optimal solution and may have to be satisfied with a "reasonable" one reached after a few trials. Suppose Walters Company is satisfied with the cost figure of \$480 and the flow graph of Figure 9.7. The problem may not be solved yet. Often a sixth step is necessary:

INTERDEPARTMENTAL FLOW GRAPH

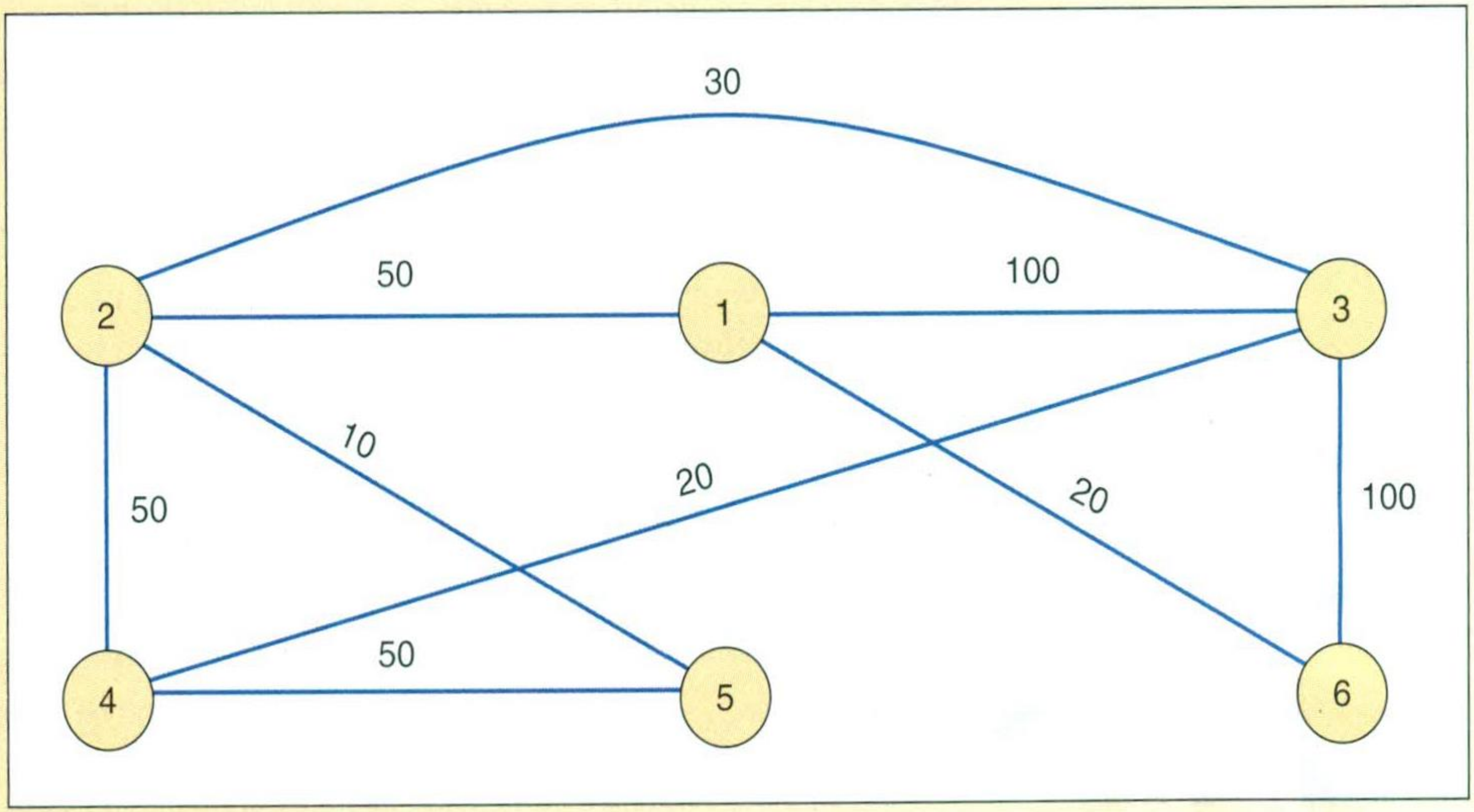


FIGURE 9.7 ■ Second Interdepartmental Flow Graph

PROCESS LAYOUT

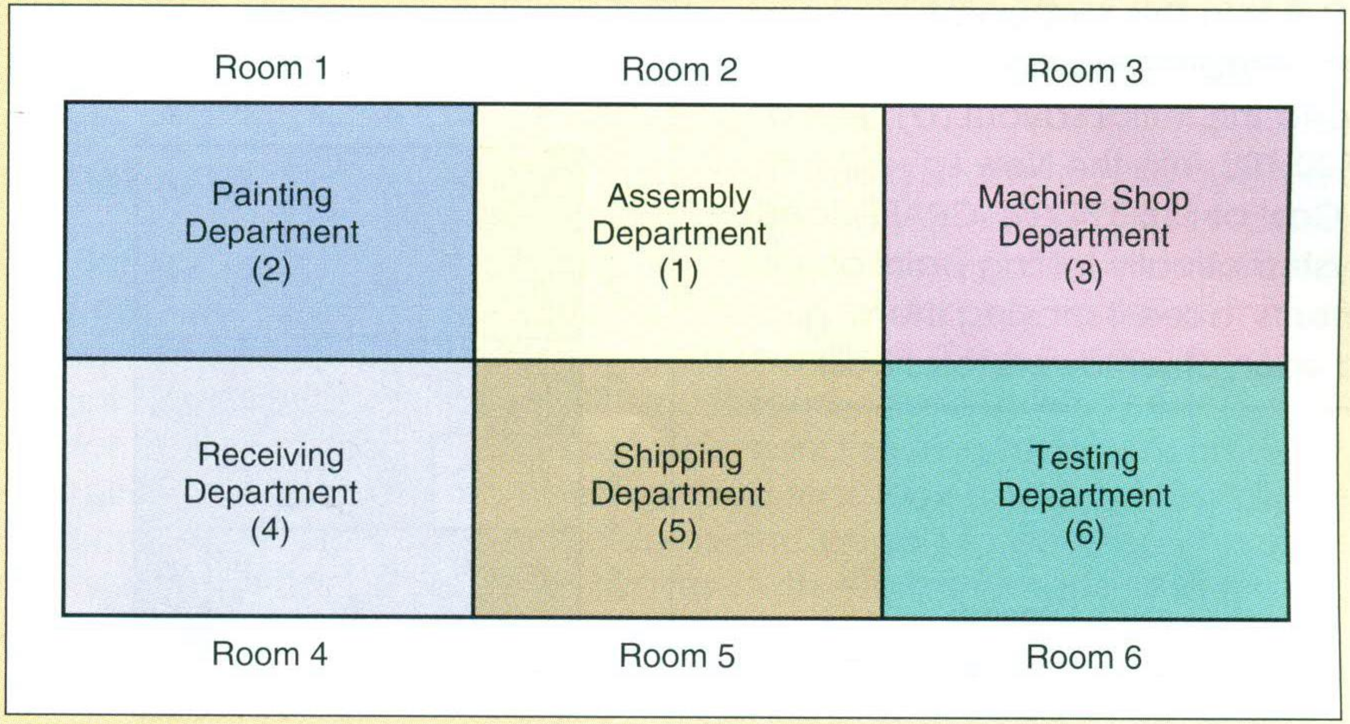


FIGURE 9.8 ■ A Feasible Layout for Walters Company

Step 6: *Prepare a detailed plan* arranging the departments to fit the shape of the building and its nonmovable areas (such as the loading dock, washrooms, and stairways). Often this step involves ensuring that the final plan can be accommodated by the electrical system, floor loads, aesthetics, and other factors.

THE END

- QUESTIONS?