8

Facility Decisions: Layouts

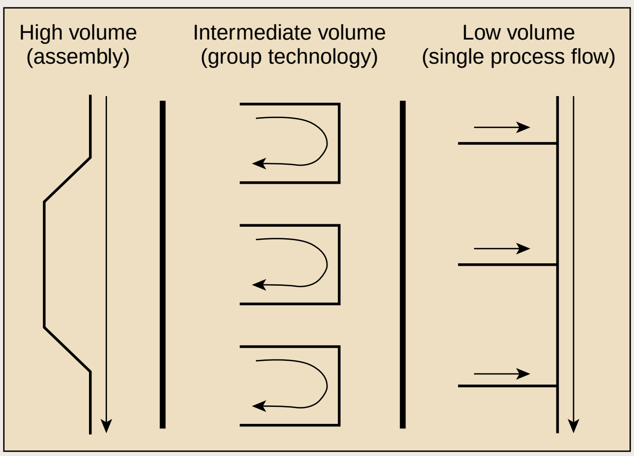
Chapter Objectives

- Introduce the different types of facility layouts that can be used in designing manufacturing and service operations.
- Present a methodology for designing a process-oriented layout.
- Introduce the concept of takt time and its relationship to the output capacity of a product-oriented layout.
- Identify the various steps and elements that are involved in balancing an assembly line.
- Discuss the current trends in facility layouts given today's shorter product life cycles and the customer's increasing desire for customized products.

TACO'S NEW FACTORY LAYOUT REDUCES INVENTORIES AND THROUGHPUT TIMES

In the early 1990s, when John White Jr. became president of TACO, he found the factory floor crammed with inventories and delivery times for products taking weeks and even months. Not coincidentally, this was about the same amount of time it took for a product to make its way through the factory floor from beginning to end. The factory layout was designed according to processes, with all of the machining taking place in one area, assembly taking place in another, painting in a third area, and so forth. As a result, TACO's products spent a lot of time traveling from one work area to the next, often waiting for long periods of time before the required operation was performed. These long waits were the reasons there was so much inventory on the floor.

Taco Plant Layout



TACO is an old traditional New England manufacturer located in Cranston, Rhode Island. It has been producing circulator pumps since the early part of the 20th century when John's grandfather started the business. (Circulator pumps are used in forced hot water heating systems to move the water through the pipes.) TACO makes both residential and industrial circulator pumps. The former are made in very high volumes, whereas the latter are produced in much lower volumes, often being designed and made to order to meet the specific requirements of an individual building.

After analyzing the various products being produced, TACO redesigned its factory layout to be product-oriented rather than process-oriented. The three main bays in its factory were divided into three major product lines. One bay was devoted to the high-volume residential pump, where an assembly-line process was installed. In the middle bay, group technology cells were established, with each cell focusing on a specific family of products. In this bay, the pumps were produced in varying batch sizes of between 100 and 600 units. All of the different pieces of equipment required to make a particular family of pumps were organized in a U-shape layout in the sequential order required to make the pump, and there were several cells in the bay. Thus, a typical work cell would consist of machine tools, an assembly area, and even a small paint booth.

The third bay does all of the low-volume products, which are often the large bulky commercial units. The volumes here are very low, sometimes being as little as one or two units of a specific design. The layout in this bay uses a single-process flow approach, which in many ways resembles an assembly line. The main difference here is that the time spent at each station is very long compared to a traditional assembly line, and each station is designed so that it is very flexible in order to accommodate the wide variety of products that are made in this bay.

TACO's new product-oriented layouts have reduced the work-in-process inventories by more than 30 percent, while at the same drastically reducing the average throughput time by more than 50 percent. Products that once took weeks and even months to complete are now manufactured in days, and even hours if necessary. Another benefit of the new layouts is that TACO has been able to increase its output by more than 50 percent without requiring any additional floor space. TACO's new factory layout is one of the major reasons that it currently has a major share of the markets in which its products compete.

Source: TACO.

Types of Manufacturing Layouts

process layout

Similar operations are performed in a common or functional area, regardless of the product in which the parts are used.

product layout

Equipment/operations are located according to the progressive steps required to make the product.

There are three basic types of layouts that have been identified in manufacturing plants: (*a*) process layout, (*b*) product layout, and (*c*) fixed-position layout. In addition, there is one hybrid that is referred to as a group technology or cellular layout, which is a combination of process and product layouts. We discuss all of these in detail except for the fixed-position layout. As a starting point for this discussion, Exhibit 8.1 presents the general characteristics of a good layout for both manufacturing and service operations.

In a **process layout** (also called a *job-shop layout* or *layout by function*), similar equipment or functions are grouped together, such as in a machine shop where all the lathes are in one area and all the stamping machines are in another. A part being worked on travels from one area to the next, according to the specific sequence of operations required. This type of layout is often found in high-mix, low-volume manufacturing plants that have an intermittent process.

A **product layout** (also called a *flow-shop layout*) is one in which equipment or work processes are arranged according to the progressive steps by which the product is made. If equipment is dedicated to the continual production of a narrow product line, this is usually

Managerial Issues

Managers need to take many factors into consideration when determining which type of facility layout is most appropriate for their operations. This applies to both manufacturing and service operations alike. Product-oriented layouts like assembly lines, as we shall see, are highly efficient but tend to be very inflexible. Process-oriented layouts, on the other hand, are very flexible, in terms of the wide variety of products that can be made, but, as we saw at TACO in the opening vignette, they typically have significant work-in-process inventories and are relatively inefficient and slow.

The choice of which type of layout to adopt cannot be made lightly because it can significantly impact a company's long-term success, both in terms of product costs and its ability to compete successfully in the marketplace. In addition, the investment costs that are associated with installing a particular layout, in terms of time and money, are substantial.

The manager's goal in selecting a layout is to provide a smooth flow of material through the factory, or an uncomplicated traffic pattern for both customers and workers in a service operation. Today, there are many software packages available to assist managers in designing a layout that is both efficient and effective, as illustrated in the OM in Practice box.

Exhibit 8.1

Characteristics of a Good Layout

Manufacturing and Back-Office Service Operations	Face-to-Face Services
1. Straight-line flow pattern (or adaptation).	**1.** Easily understood service-flow pattern.
2. Backtracking kept to a minimum.	**2.** Proper waiting facilities.
3. Production time predictable.	**3.** Easy communication with customers.
4. Little interstage storage of materials.	**4.** Customer surveillance easily maintained.
5. Open plant floors so everyone can see what's going on.	**5.** Clear exit and entry points with sufficient checkout capabilities.
6. Bottleneck operations under control.	**6.** Departments and processes arranged so that customers see only what you want them to see.
7. Workstations close together.	**7.** Balance between waiting areas and service areas.
8. Minimum material movement.	**8.** Minimum walking.
9. No unnecessary rehandling of materials.	**9.** Lack of clutter.
10. Easily adjustable to changing conditions.	**10.** High sales volume per square foot of facility.

called a *production line* or *assembly line*. Examples are the manufacture of small appliances (toasters, irons, beaters), large appliances (dishwashers, refrigerators, washing machines), electronics (computers, CD players), and automobiles.

A **group technology (GT) or cellular layout** brings together dissimilar machines into work centers (or cells) to work on products that have similar shapes and processing requirements. A GT layout is similar to process layout, in that cells are designed to perform a specific set of processes, and it is similar to product layout in that the cells are dedicated to a limited range of products. Often the cell is arranged in a U-shape to allow workers to move more easily from one station to another.

group technology (G/T) or cellular layout

Groups of dissimilar machines brought together in a work cell to perform tasks on a family of products that share common attributes.

In a **fixed-position layout,** by virtue of its bulk or weight, the product remains stationary at one location. The manufacturing equipment is moved to the product rather than vice versa. Shipyards and construction sites are good examples of this format.

fixed-position layout

The product, because of its size and/or weight, remains in one location and processes are brought to it.

Many manufacturing facilities often have a combination of two layout types. For example, a given floor may be laid out by process, while another floor may be laid out by

Operations Management in Practice

IMPROVING A MANUFACTURING PROCESS USING PLANNING SOFTWARE

A challenge many facilities planners face today is finding a way to quickly and effectively evaluate proposed layout changes and material handling systems so that the material handling costs and distances are minimized. This challenge was addressed during a three-day, on-site software training session conducted at an appliance manufacturer. The facilities planners were learning the basics on using the FactoryFLOW software package, a computer-based, facilities planning tool developed by Cimtechnologies Corp. The training group evaluated a current layout proposal of a console assembly area to see if any improvements could be made.

The FactoryFLOW software quantitatively evaluates facility layouts and material handling systems by showing the material flow paths and costs, both in output text reports and in a graphic overlay of an AutoCAD layout drawing. FactoryFLOW evaluates the material flow and material handling costs and distances using the following input information: an AutoCAD layout drawing, part routing data (i.e., part names, from/to locations, and move quantities), and material handling system characteristics (i.e., fixed and variable costs, load/unload times, and speeds).

The facilities planners had a drawing of the area, and the industrial engineers supplied the part routing and material equipment information; therefore data entry and analysis of the current layout took about one-half of a day. Output diagrams and reports showed material handling distances of over 407 million feet per year and material handling costs of just over $900,000 per year.

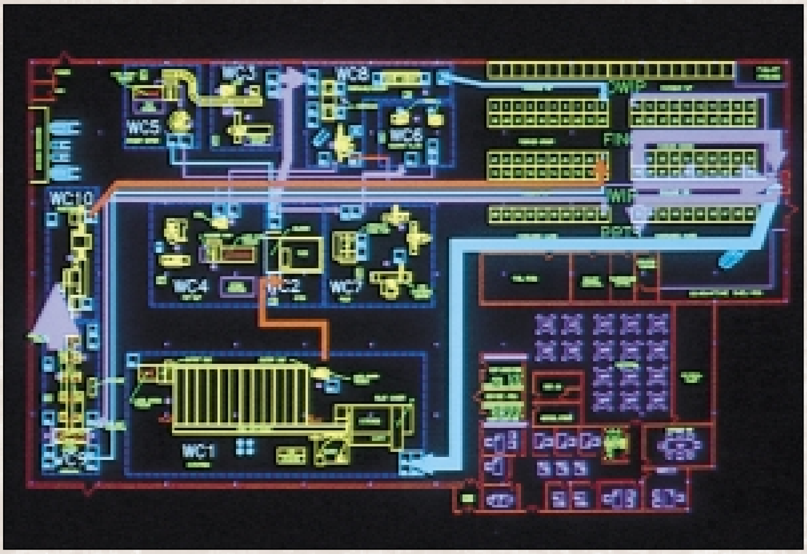
The second half of the day was used to come up with alternative layouts by analyzing the output text reports and the material flow lines. One alternative was to rotate a line of 16 plastic presses 90 degrees, so they fed right into the subassembly area, and to rotate the main console assembly lines 90 degrees, so they were closer to the same area. Since the primary material handling system was an overhead conveyor, minimizing the length of the conveyor was a major concern. FactoryFLOW was used to evaluate the alternative layout, and the output reports showed the material handling costs had been reduced by over $100,000 to $792,265 per year. Also, by decreasing the material travel distance, the length of overhead conveyor needed had been reduced from 3,600 feet to just over 700 feet.

product. It is also common to find an entire plant arranged according to general product flow (fabrication, subassembly, and final assembly), coupled with process layout within fabrication and product layout within the assembly department. Likewise, group technology is frequently found within a department that itself is located according to a plantwide process-oriented layout.

An operation's layout continually changes over time because the internal and external environments are dynamic. As demands change, so can layout. As technology changes, so can layout. In Chapter 3, we discussed a product/process matrix indicating that as products and volumes change, the most efficient layout is also likely to change. Therefore, the decision on a specific layout type may be a temporary one.

Process Layout

The most common approach for developing a process layout is to arrange departments consisting of similar or identical processes in a way that optimizes their relative placement. In many installations, optimal placement often translates into placing departments with large amounts of interdepartmental traffic adjacent to one another. The primary goal in designing a layout for a manufacturing or distribution facility is to minimize material handling costs. In a service organization, the main objective is to minimize customer and worker travel time through the process.



FactoryFLOW integrates material handling data and a layout drawing to compute material handling distances, costs, and equipment utilization.

The FactoryFLOW software made it possible to complete this project in a short amount of time, and the facilities planners at this company now have a tool for further evaluation of facility layouts and material handling systems.

Source: "Factory Planning Software Cimtechnologies Corp. (Ames, IA)," *Industrial Engineering,* December 1993, p. SS3.

Minimizing Interdependent Movement Costs Consider the following simple example:

Example

Suppose that we want to arrange the six departments of a toy factory to minimize the interdepartmental material handling cost. Initially, let us make the assumption that all departments have the same amount of space, say 40 feet by 40 feet, and that the building is 80 feet wide and 120 feet long (and thus compatible with the department dimensions). The first thing we would want to know is the nature of the flow between departments and the way the material is transported. If the company has another factory that makes similar products, information about flow patterns might be obtained from these records. On the other hand, if this is a new product, such information would have to come from routing sheets or from estimates by knowledgeable personnel such as process or industrial engineers. Of course these data, regardless of their source, have to be adjusted to reflect the nature of future orders over the projected life of the proposed layout.

Let us assume that this information is available. We find that all material is transported in a standard-size crate by forklift truck, one crate to a truck (which constitutes one "load"). Now suppose that transportation costs are $1 to move a load between adjacent departments and $1 extra for each department in between. (We assume there is two-way traffic between departments.) The expected loads between departments for the

Exhibit 8.2
Interdepartmental Flow

	1	2	3	4	5	6
1		175	50	0	230	20
2			0	100	165	80
3				17	213	99
4					25	0
5						554
6						

Exhibit 8.3
Building Dimensions and Departments

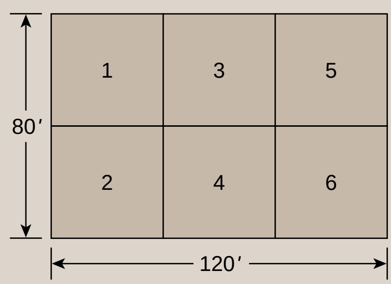
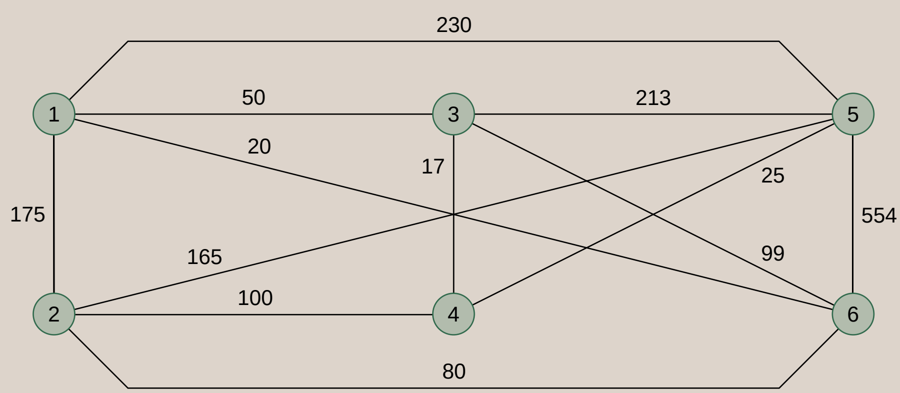


Exhibit 8.4
Interdepartmental Flow Graph with Number of Annual Movements



first year of operation are tabulated in Exhibit 8.2; the available plant space is depicted in Exhibit 8.3.

Solution

Given this information, our first step is to illustrate the interdepartmental flow by a model, such as Exhibit 8.4, which is Exhibit 8.2 displayed in the building layout in Exhibit 8.3. This provides the basic layout pattern, which we are trying to improve.

Exhibit 8.5

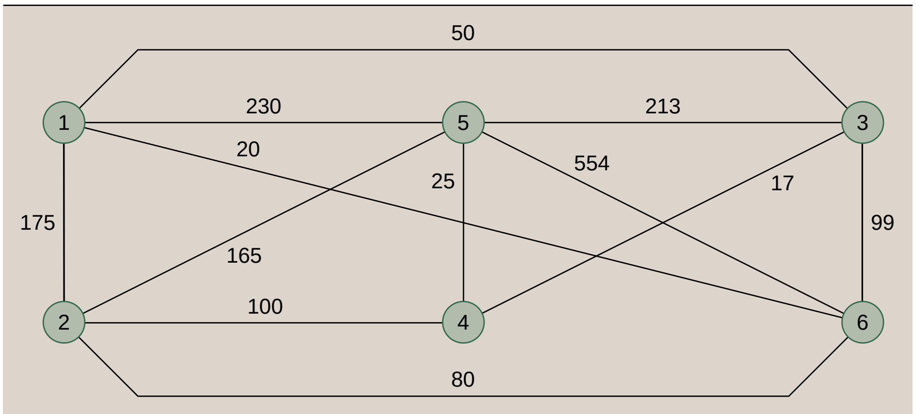
Cost Matrix—First Solution

	1	2	3	4	5	6
1		175	50	0	460	40
2			0	100	330	160
3				17	213	99
4					25	0
5						554
6						

Total cost: $2,223

Exhibit 8.6

Revised Interdepartmental Flowchart*



*Only interdepartmental flow with effect on cost is depicted.

The second step is to determine the annual cost of this layout by multiplying the material handling cost per load by the number of loads moved between each department. Exhibit 8.5 presents this information, which is derived as follows: The annual material handling cost between Departments 1 and 2 is $175 ($1 × 175 moves), $460 between Departments 1 and 5 ($2 × 230 moves), and so forth. (The distances are taken from Exhibit 8.3 or 8.4, not Exhibit 8.2.)

The third step is a search for departmental changes that reduce costs. On the basis of the graph and the cost matrix, it appears desirable to place Departments 1 and 5 closer together to reduce their high move-distance costs. However, this requires shifting another department, thereby affecting other move-distance costs and the total cost of the second solution. Exhibit 8.6 shows the revised layout resulting from relocating Department 5 and an adjacent department (Department 3 is arbitrarily selected for this purpose). The revised cost matrix for the exchange, with the cost changes circled, is given in Exhibit 8.7. Note the total cost is now $345 less than in the initial solution. While this trial-and-error approach resulted in a lower total cost in this case, even in a small problem, it is often difficult to identify the correct "obvious move" on the basis of casual inspection. The revised layout for the facility is shown in Exhibit 8.8.

Exhibit 8.7

Cost Matrix—Second Solution

	1	2	3	4	5	6		Net cost change
		175	100	0	230	40	1	+50−230
			0	100	165	160	2	−165
				17	213	99	3	
					25	0	4	
						554	5	
							6	

Total cost: $1,878

Total difference: −345

Exhibit 8.8

Revised Building Layout

1	5	3
2	4	6

Thus far, we have shown only one exchange among a large number of potential exchanges; in fact, for a six-department problem there are 6! (or 720) possible arrangements. Therefore, the procedure we have employed would have only a remote possibility of achieving an optimal combination in a "reasonable" number of tries. Nor does our problem stop here. Other factors must be taken into consideration.

Suppose that we are able to arrive at a good trial-and-error solution solely on the basis of material handling cost. Continuing with our toy factory example, locating the sewing department next to the painting department might not only be hazardous, but also may result in defective products with lint, thread, and cloth particles drifting onto the painted items before they can dry. Thus, issues like these also must be incorporated into the final choice of layout.

Product Layout

When product demand is sufficiently high and sustainable over a long period of time, it is usually cost effective to rearrange resources from a process layout to a product layout as defined by the sequence of steps required to make the product. We often call these *assembly* lines, although the ratio of direct manual labor to machine work can vary widely. Assembly lines can vary from virtually 100 percent parts assembly by workers, to the other extreme, an *automated transfer* line, where all direct work is done by machine. In between are all types: Automobile lines have tools ranging from simple hammers and wrenches to robotic welding and painting. Assembly lines in electronics also can range widely from manual parts assembly to equipment for automatic parts insertion, automatic soldering, and automatic testing.

Assembly Lines Assembly lines are a special case of product layout. In a general sense, the term assembly line refers to a progressive assembly linked by some type of material handling device. The usual assumption is that some form of pacing is present, and the allowable processing time is equivalent for all workstations. Within this broad definition, there are important differences among line types. A few of these are material handling devices (belt or roller conveyor, overhead crane), line configuration (U-shape, straight, branching), pacing (machine, human), product mix (one product or multiple products), workstation characteristics (workers may sit, stand, walk with the line, or ride the line), and length of the line (few or many stations).

The range of products partially or completely assembled on lines includes toys, appliances, autos, garden equipment, perfumes and cosmetics, and a wide variety of electronic components. In fact, it is probably safe to say that virtually any product with multiple parts and produced in large volume uses assembly lines to some degree. Clearly, assembly lines are an important technology; to really understand their managerial requirements one must have some familiarity with how a line is balanced.

An important consideration that should not be overlooked in designing assembly lines is the human factor. Early assembly lines were machine paced; that is, they moved at a predetermined pace, regardless of whether or not the work was completed at a station. Under this structure, workers who fell behind had to rush to complete their assigned tasks, with the result often being faulty workmanship.

In recent years, worker-paced assembly lines, advocated initially by Japanese manufacturers, have replaced machine-paced lines in many facilities. With the worker-paced line, the operator continues to work on the product until the work assigned is satisfactorily completed. Only then is the product allowed to move on to the next station. The quality of the products made on a worker-paced line is significantly higher than that of products made on a comparable machine-paced line. When a Japanese manufacturer took over the production of televisions from a U.S. company, the number of defects dropped from 160 defects per 100 TVs to 4 defects per 100 TVs, even though the output per day and the workforce remained virtually unchanged. This dramatic increase in quality was attributed, in large part, to the installation of a worker-paced assembly line that replaced the previously existing machine-paced line.[1]

Definitions. Before we begin our analysis of assembly lines, there are two terms that need to be defined, and that are illustrated in Exhibit 8.9.

- *Product interval time.* The product interval time is the actual time between products being completed at a station. This is often referred to as *cycle time*, or more recently, **takt time** (from the Swedish word meaning "cycle or cycle time").[2] As we shall see shortly, the takt time for an assembly line determines the capacity of that line. We will use takt time to describe the product interval time in our analyses.
- *Product duration time.* The overall time it takes to complete an individual product, from start to finish, is known as the product's **throughput time,** and is also referred to as cycle time, especially when looking at it from the customer's perspective. Throughput time is important when you are looking at the delivery time for customized products. We will use throughput time to describe the product duration time.

takt time

The time interval between stations on an assembly line.

throughput time

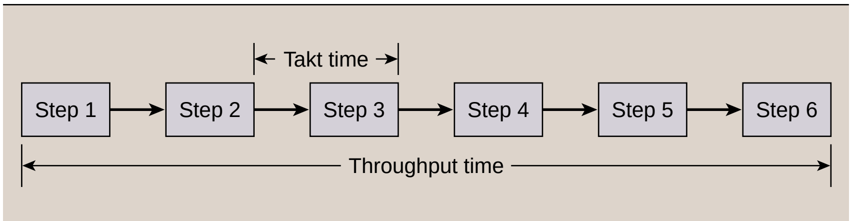
The overall elapsed time from when the manufacture of a product is first begun to when that specific product is completed.

[1]Lloyd Dobyns and Frank Reuven, *If Japan Can, Why Can't We?* (New York: NBC-TV News Presentation, June 24, 1980).

[2]Robert W. Hall, "Time Prints and Takt Times," *Target: Innovation at Work* 14, no. 3 (1998), pp. 6–13.

Exhibit 8.9

Illustrating Takt Time and Throughput Time on an Assembly Line



Assembly line balancing. An assembly line consists of a series of workstations, each with a uniform time interval that is referred to as a takt time (which is also the time between successive units coming off the end of the line). At each workstation, work is performed on a product by adding parts and/or by completing an assembly operation. The work performed at each station is made up of many *tasks* (also referred to as *elements*, or *work units*). Such tasks are described by motion-time analysis. Generally, they are groupings that cannot be subdivided on the assembly line without paying a high penalty in extra motions.

assembly line balancing

Assignment of tasks to workstations within a given cycle time and with minimum idle worker time.

The total work to be performed at a workstation is equal to the sum of the tasks assigned to that workstation. The **assembly line balancing** problem is one of assigning all of the tasks required to a series of workstations so that the time required to do the work at each station does not exceed the takt time, and at the same time, the unassigned (i.e., idle) time across all workstations is minimized. An additional consideration in designing the line is to assign the tasks as equitably as possible to the stations. The problem is further complicated by the relationships among tasks imposed by product design and process technologies. This is called the precedence relationship, which specifies the order in which the tasks must be performed in the assembly process.

Steps in assembly line balancing. The sequence of steps required to balance an assembly line is straightforward:

1. Specify the sequential relationship among tasks using a precedence diagram. The diagram consists of circles and arrows. Circles represent individual tasks; arrows indicate the order of task performance.
2. Determine the required takt time (T), using the following formula:

$$T = \frac{\text{Production time per day}}{\text{Output per day (in units)}}$$

3. Determine the theoretical minimum number of workstations (N_t) required to satisfy the takt time constraint, using the following formula:

$$N_t = \frac{\text{Sum of task times } (S)}{\text{Takt time } (T)}$$

4. Select a primary rule by which tasks are to be assigned to workstations, and a secondary rule to break ties.
5. Assign tasks, one at a time, to the first workstation until the sum of the task times is equal to the takt time, or no other tasks are feasible because of time or sequence restrictions. Repeat the process for Workstation 2, Workstation 3, and so on, until all tasks are assigned.
6. Evaluate the efficiency of the resulting assembly line using the following formula:

$$\text{Efficiency} = \frac{\text{Sum of task times } (S)}{\text{Actual number of workstations } (N_a) \times \text{Takt time } (T)}$$

7. If efficiency is unsatisfactory, rebalance the line using a different decision rule.

Example

A toy company produces a Model J Wagon that is to be assembled on a conveyor belt. Five hundred wagons are required per day. The company is currently operating on a one-shift, eight-hour-a-day schedule, with one hour off for lunch (i.e., net production time per day is seven hours). The assembly steps and times for the wagon are given in Exhibit 8.10. Assignment: Find the balance that minimizes the number of workstations, subject to takt time and precedence constraints.

Solution

1. Draw a precedence diagram. Exhibit 8.11 illustrates the sequential relationships identified in Exhibit 8.10. (The length of the arrows has no meaning.)
2. Takt time determination. Here we have to convert to seconds since our task times are in seconds.

$$T = \frac{\text{Production time per day}}{\text{Output per day}} = \frac{7 \text{ hrs./day} \times 60 \text{ min./hr.} \times 60 \text{ sec./min.}}{500 \text{ wagons}}$$

$$= \frac{25{,}200}{500} = 50.4 \text{ seconds}$$

3. Theoretical minimum number of workstations required (the actual number may be greater):

$$N_t = \frac{S}{T} = \frac{195 \text{ seconds}}{50.4 \text{ seconds}} = 3.86 \text{ stations} \quad \rightarrow \quad 4 \text{ stations}$$

(Since we cannot have a fraction of a station, we always round up to the next whole integer. For this example, the minimum number of stations is four.)

4. Select assignment rules. Research has shown that some rules are better than others for certain problem structures. In general, the strategy is to use a rule assigning tasks that either have many followers or are of long duration since they effectively limit the balance achievable. In this case, we use as our primary rule
   a. Assign tasks in order of the largest number of following tasks. Our secondary rule, to be invoked where ties exist from our primary rule, is
   b. Assign tasks in order of longest operating time.

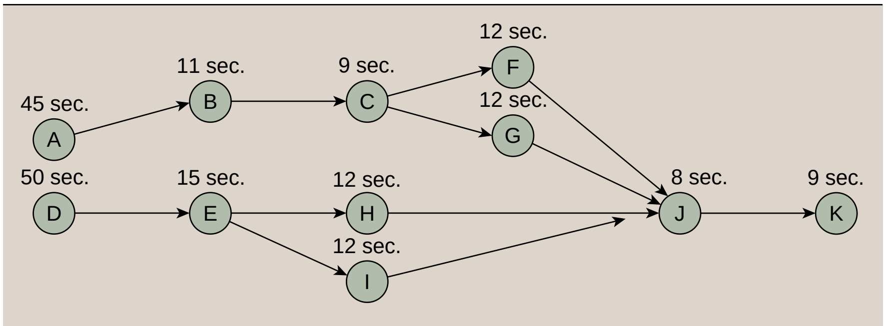
Exhibit 8.10

Assembly Steps and Times for Model J Wagon

Task	Performance 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 hub cap	C
G	12	Position front wheel #2 and fasten hub cap	C
H	12	Position front wheel #1 and fasten hub cap	E
I	12	Position rear wheel #2 and fasten hub cap	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 8.11

Precedence Graph for Model J Wagon



Task	Total Number of Following Tasks	Following Tasks
A	6	B, C, F, G, J, K
B or D	5	C, F, G, J, K (for B)
C or E	4	H, I, J, K (for E)
F, G, H, or I	2	J, K
J	1	K
K	0	—

5. Make task assignments to form Workstation 1, Workstation 2, and so forth, until all tasks are assigned. The actual assignment is given in Exhibit 8.12A and is shown graphically in Exhibit 8.12B.
6. Calculate the efficiency. This is shown in Exhibit 8.12C.
7. Evaluate the solution. An efficiency of 77 percent indicates an imbalance or idle time of 23 percent (1.0 − 0.77) across the entire line. From Exhibit 8.12A we can see that there are 57 total seconds of idle time, and the "choice" job is at Workstation 5.

Is a better balance possible? In this case, yes. Try balancing the line with rule *b* and breaking ties with rule *a*. (This will give you a feasible four-station balance.)

Often the longest required task time dictates the shortest possible takt time for the production line. This task time becomes the lower time bound, unless it is possible to split the task into two or more workstations.

Example

Consider the following illustration: Suppose that an assembly line contains the following task times in seconds: 40, 30, 15, 25, 20, 18, 15. The line runs for 7½ hours per day and demand for output is 750 wagons per day.

Solution

The takt time required to produce 750 wagons per day is 36 seconds ([7½ × 60 minutes × 60 seconds]/750). How do we deal with the task that is 40 seconds long?

There are several ways that we may be able to accommodate the 40-second task in a line with a 36-second takt time. The possibilities include

1. *Split the task.* Can we split the task so that complete units are processed in two workstations?

Exhibit 8.12A
Balance Made According to Largest Number of Following Tasks Rule

	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.

Exhibit 8.12B
Precedence Graph for Model J. Wagon

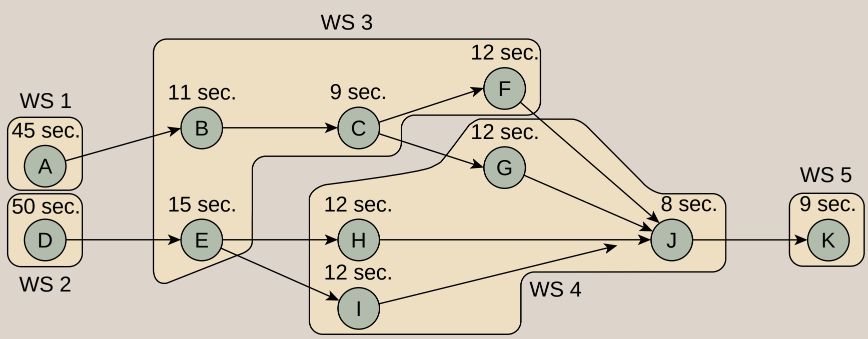


Exhibit 8.12C
Efficiency Calculation

$$\text{Efficiency} = \frac{S}{NT}$$

$$= \frac{195}{(5)(50.4)} = 0.77, \text{ or } 77\%$$

2. *Duplicate the station.* By duplicating the task at two stations, the effective task time is reduced by 50 percent. If necessary, additional stations can be assigned to the same task to further lower the effective task time. Often with this approach, several tasks may be combined into one station to increase efficiency. In the example given, the first two tasks with 40 and 30 seconds each would be combined into one station, which would then be duplicated. The effective takt time for this station is then 35 seconds ([40 + 30]/2), which is below the required cycle time of 36 seconds.
3. *Share the task.* Can the task somehow be shared so an adjacent workstation does part of the work? This differs from the split task in the first option because the adjacent station acts to assist, not to do some units containing the entire task.

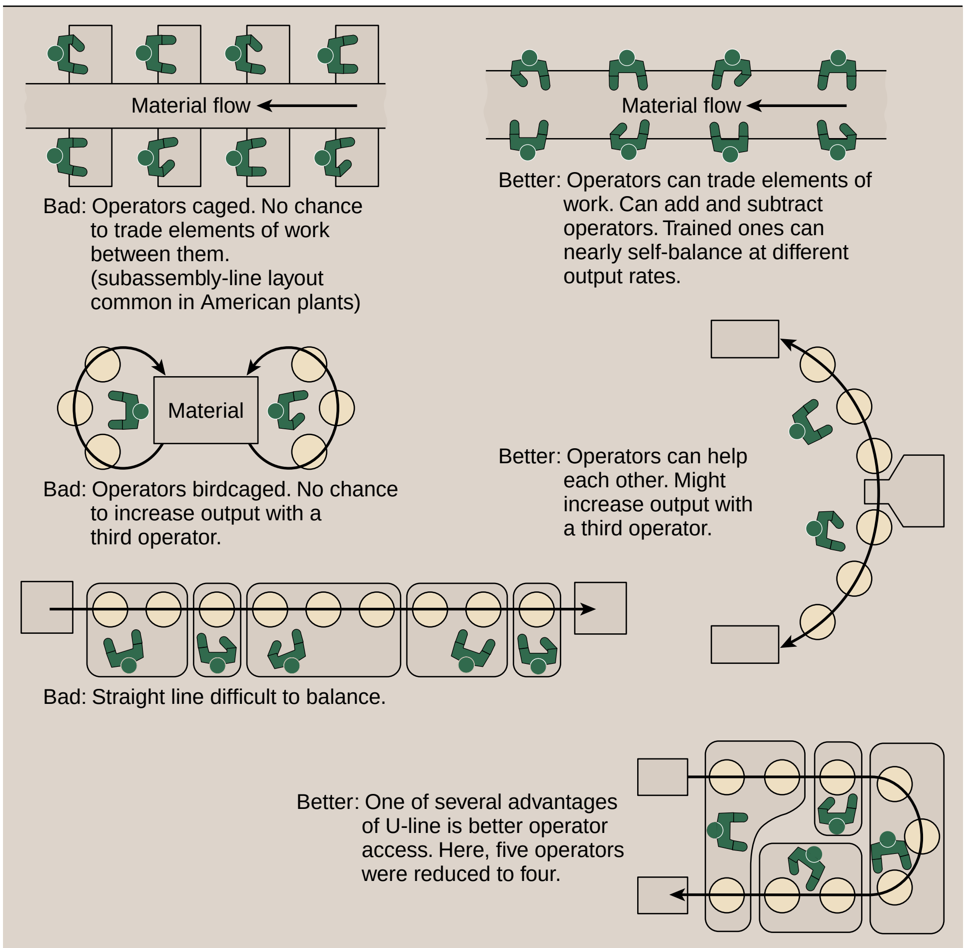
4. *Use a more skilled worker.* Since this task exceeds the cycle time by just 11 percent, a faster worker may be able to meet the 36-second time.
5. *Work overtime.* Producing at a rate of one unit every 40 seconds would produce 675 wagons per day, 75 short of the needed 750. The amount of overtime required to do the additional 75 wagons is 50 minutes (75 × 40 seconds/60 seconds).
6. *Redesign.* It may be possible to redesign the product to reduce the task time slightly.

Other possibilities to reduce the task time include equipment upgrading, a roaming helper to support the line, a change of materials, and multiskilled workers to operate the line as a team rather than as independent workers.

Flexible line layouts. As we saw in the preceding example, assembly line balancing frequently results in unequal workstation times. In fact, the shorter the takt time, the greater the probability of a higher percentage of imbalance in the line. Flexible line layouts such as those shown in Exhibit 8.13 are a common way of dealing with this problem. In our toy

Exhibit 8.13

Flexible Line Layouts



Source: Robert W. Hall, *Attaining Manufacturing Excellence* (Homewood, IL: Dow Jones-Irwin, 1987), p. 125.

company example, the U-shaped line with work sharing at the bottom of the figure could help resolve the imbalance.

Mixed-model line balancing. To meet the demand for a variety of products and to avoid building high inventories of one product model, many manufacturers often schedule several different models to be produced over a given day or week on the same line. To illustrate how this is done, suppose our toy company has a fabrication line to bore holes in its Model J Wagon frame and its Model K Wagon frame. The time required to bore the holes is different for each wagon type.

Example

Assume that the final assembly line downstream requires equal numbers of Model J and Model K wagon frames. Also assume that we want to develop a takt time for the fabrication line, which is balanced for the production of equal numbers of J and K frames. Of course, we could produce Model J frames for several days and then produce Model K frames until an equal number of frames have been produced. However, this would build up unnecessary work-in-process inventory.

If we want to reduce the amount of work-in-process inventory, we could develop a cycle mix that greatly reduces inventory buildup while keeping within the restrictions of equal numbers of J and K wagon frames.

Solution

Process times: 6 minutes per J and 4 minutes per K.

The day consists of 480 minutes (8 hours $\times$ 60 minutes).

$$6J + 4K = 480$$

Since equal numbers of J and K are to be produced (or $J = K$), produce 48J and 48K per day, or 6J and 6K per hour.

The following shows one balance of J and K frames.

Balanced Mixed-Model Sequence

Model sequence	J J	K K K	J J	J J	K K K	Repeats
Operation time	6 6	4 4 4	6 6	6 6	4 4 4	8 times
Minitakt time	12	12	12	12	12	per day
Total takt time			60			

This line is balanced at six wagon frames of each type per hour with a minitakt time of 12 minutes.

Another balance is J K K J K J, with times of 6, 4, 4, 6, 4, 6. This balance produces three J and three K every 30 minutes with a minitakt time of 10 minutes (JK, KJ, KJ).

The simplicity of mixed-model balancing (under conditions of a level production schedule) is seen in Yasuhiro Mondon's description of Toyota Motor Corporation's operations:

1. Final Assembly lines of Toyota are mixed product lines. The production per day is averaged by taking the number of vehicles in the monthly production schedule classified by specifications, and dividing by the number of working days.

2. In regard to the production sequence during each day, the cycle time of each different specification vehicle is calculated and in order to have all specification vehicles appear at their own cycle time, different specification vehicles are ordered to follow each other.[3]

The mixed-model line appears to be a relatively straightforward sequencing problem. This is because in our example the two models fit nicely into a common time period that also matched demand. From a mathematical standpoint, designing a mixed-model line is very difficult and no technique exists to provide the optimum assignment of tasks to workstations. This is because the mixed-model line involves multiple lot sizes, lot sequencing, setup times for each lot, differing workstation sizes along the line, and task variations. The problem is to design the assembly line and workstations and to specify exactly which tasks are to be done in each.

The objectives of a mixed-model line design are to minimize idle time and minimize the inefficiencies caused by changing from model to model. Researchers have used integer programming, branch and bound techniques, and simulation. They still are not able to find the optimal solution for a realistic sized, real-world problem.

Current Thoughts on Assembly Lines

It is true that the widespread use of assembly-line methods in manufacturing has dramatically increased output rates. Historically, the focus almost always has been on full utilization of human labor; that is, to design assembly lines minimizing human idle times. Equipment and facility utilization stood in the background as much less important. Past research tried to find optimal solutions as if the problem stood in a never-changing world.

Newer views of assembly lines take a broader perspective. Intentions are to incorporate greater flexibility in the number of products manufactured on the line, more variability in workstations (such as size, number of workers), improved reliability (through routine preventive maintenance), and high-quality output (through improved tooling and training). (See also the OM in Practice on How Ford Achieves Flexibility on the Assembly Line.)

Group Technology (Cellular) Layout

A group technology (or cellular) layout allocates dissimilar machines into cells to work on products that have similar weights, shapes, and processing requirements. Group technology (GT) layouts are now widely used in metal fabricating, computer chip manufacture, and assembly work. The overall objective is to gain the benefits of product layout in job-shop kinds of production. These benefits include

1. *Better human relations.* Cells consist of a few workers who form a small work team; a team turns out complete units of work.
2. *Improved operator expertise.* Workers see only a limited number of different parts in a finite production cycle, so repetition means quick learning.
3. *Less work-in-process inventory and material handling.* A cell combines several production stages, so fewer parts travel through the shop.
4. *Faster production setup.* Fewer jobs mean reduced tooling and hence faster tooling changes.

[3]S. Manivannan and Dipak Chudhuri, "Computer-Aided Facility Layout Algorithm Generates Alternatives to Increase Firm's Productivity," *Industrial Engineering,* May 1984, pp. 81–84.

Operations Management in Practice

HOW FORD ACHIEVES FLEXIBILITY ON THE ASSEMBLY LINE

Ford Motor Company's assembly plant in Wixom, Michigan, provides another good example of how, with careful planning, several different products can be made on assembly lines. The Wixom plant produces the Mark VIII, the Lincoln Continental, and the Lincoln Town Car. To further complicate the situation, the Continental is a front-wheel drive vehicle on a unibody chassis, whereas the Town Car and the Mark VIII are rear-wheel drive models mounted on a standard frame chassis. The line producing the Continental and the Town Car can be balanced by having between 67 percent and 75 percent of the cars be rear-wheel drive models. Although the Mark VIII is assembled on its own line, all three models share the same paint shop. Currently, the output from the Mark VIII line is 10 cars per hour, and the Continental/Town Car line produces 42 cars per hour.

Developing a GT Layout Shifting from process layout to a GT cellular layout entails three steps:

1. Grouping parts into families that follow a common sequence of steps. This step requires developing and maintaining a computerized parts classification and coding system. This is often a major expense with such systems, although many companies have developed short-cut procedures for identifying parts-families.
2. Identifying dominant flow patterns of parts-families as a basis for location or relocation of processes.
3. Physically grouping machines and processes into cells. Often some parts cannot be associated with a family and specialized machinery cannot be placed in any one cell because of its general use. These unattached parts and machinery are placed in a "remainder cell."

Facility Layouts for Services

The overall goal in designing a layout for a service facility, from an operations perspective, is to minimize travel time for workers, and, often, also for customers when they are directly involved in the process. From a marketing perspective, however, the goal is usually to maximize revenues. Frequently these two goals are in conflict with each other. It is therefore management's task to identify the trade-offs that exist in designing the layout, taking both perspectives into consideration. For example, the prescription center in a pharmacy is usually located at the rear, requiring customers to walk through the store. This encourages impulse purchases of nonprescription items.

Types of Service Layouts

We use the three basic types of manufacturing facility layouts that were described earlier in this chapter as a framework for identifying the different types of layouts that exist in service operations.

Process Layout The support services for an emergency room in a hospital provide a good example of a *process layout*, with radiology, blood analysis, and the pharmacy each being located in a specific area of the hospital. Patients requiring any of these specific services therefore must go to the respective locations where these services are provided. The

kitchen of a large restaurant also can be viewed as a process layout. Here all of the desserts and breads are prepared in the bake shop; fruits and vegetables are peeled, sliced, and diced in the prep area; and raw meats and seafood are prepared for cooking in the butcher shop. Even the cooking line often is subdivided by type of process, with all of the frying taking place in one area, broiling and roasting in another, and sauteed dishes in a third.

Product Layout A good service example of a *product layout* is a cafeteria line where all of the various stations (for example, salads, hot and cold entrees, desserts, and beverages) are arranged in a specific order, and customers visit each station as they move through the line.

Fixed-Position Layout Examples of *fixed-position layouts* in services include (*a*) an automobile repair shop (where all of the processes such as brake repair, oil change, etc., typically take place in the same location), (*b*) an operating room in a hospital (where the patient remains in a given location on the operating table), and (*c*) a table at a restaurant where all of the different courses in a meal are brought to the customer (and in some cases even prepared at the table in front of the customer).

Layout Considerations in Services

In designing facility layouts for service operations, additional, service-unique issues need to be taken into consideration. First, the cost per square foot for retail locations is usually very expensive (in comparison to manufacturing space costs). Service retail operations, therefore, must design their facilities to maximize the sales generated per square foot (or square meter). To accomplish this, operations such as restaurants have reduced the percentage of area devoted to the back-of-the-house operations, like the kitchen, to allow more area for the customer in the form of additional seating. One way this is done, as discussed in an earlier chapter, is through the use of a **quasi-manufacturing** facility or central commissary where food can be economically prepared in a relatively low-cost area. Another approach is taken by Benihana's of Tokyo, a chain of Japanese steak houses. There the strategy is to move the kitchen to the front of the house so customers can actually participate in the food preparation process.

Another service-unique factor that needs to be taken into consideration is the customer's presence in the transformation process. As a result, the decor package of the service operation plays an important role in determining the customer's overall satisfaction with the service encounter.

Mary Jo Bitner has introduced the expression **servicescape** to describe the physical surroundings in which the service takes place.[4] The servicescape of an operation comprises three major elements: (*a*) the ambient conditions, (*b*) the spatial layout and functionality, and (*c*) the signs, symbols, and artifacts.

servicescapes

Term describing the aspects of the physical surroundings in a service operation that can affect a customer's perception of the service received.

Ambient Conditions These refer to the background characteristics of the operation, including noise level, lighting, and temperature. (It often is said that the prices in restaurants are inversely related to the amount of lighting—the darker the restaurant, the more expensive the food.) Hanging lights over tables, as seen in some of the better restaurants, suggests privacy; recessed lighting in ceilings, on the other hand, as seen in many fast-food operations, send different signals to the customer.

Spatial Layout and Functionality Unlike manufacturing firms where the goal in designing a layout is to minimize the cost of moving material between areas, one of the goals of a service operation is to minimize the travel time of employees, and, in some instances, customers. At the same time, the service firm is trying to maximize revenues per customer by exposing them to as many opportunities as possible to spend their money. For example, the long lines to get into the shows at Las Vegas casinos wend their way through slot machine areas so customers will play the slots while waiting. Operations such as IKEA, a chain of Swedish furniture stores, and Stu Leonard's Dairy Store in Norwalk, Connecticut, are designed so the customer, after entering the store, must go through the entire facility to exit, not unlike a maze with a single path through it.

Signs, Symbols, and Artifacts These refer to aspects of the service operation that have social significance. For example, banks often include columns and stone to give the feeling of security. The offices of large law firms and consulting practices often are done in dark woods and thick carpets to connote success and traditional values. Waiters in tuxedos and waiters in white shirts, hats, and aprons each gives certain signals, in terms of establishing the customers' expectations of the operation.

[4]Mary Jo Bitner, "Servicescapes: The Impact of Physical Surroundings on Customers and Employees," *The Journal of Marketing,* April 1992, pp. 57–71.

Conclusion

As we saw in the opening vignette, the choice of which type of facility layout to adopt can have a significant impact on the long-term success of a firm. This decision, therefore, should not be made lightly, but only after an in-depth analysis of the operational requirements has been completed.

A major issue to be addressed in facility layout decisions in manufacturing is: How flexible should the layout be in order to adjust to future changes in product demand and product mix? Some have argued that the best strategy is to have movable equipment that can be shifted easily from place to place to reduce material flow time for near-term contracts. However, while this is appealing in general, the limitations of existing buildings and firmly anchored equipment, and the general plant disruption that is created, make this a very costly strategy.

In service systems, particularly franchises, the study of layout has become extremely important because the selected layout may become replicated at hundreds or even thousands of facilities. Indeed, a layout error in a fast-food chain has a more immediate, and generally a more far-reaching, effect on profits than a layout error in a factory.

Key Terms

assembly line balancing p. 330
fixed-position layout p. 323
group technology (G/T) or cellular layout p. 323
process layout p. 322
product layout p. 322
servicescapes p. 339
takt time p. 329
throughput time p. 329

Review and Discussion Questions

1. What kind of layout is used in a health club?
2. What is the objective of assembly line balancing? How would you deal with the situation where one worker, although trying hard, is 20 percent slower than the other 10 people on a line?
3. How do you determine the idle-time percentage from a given assembly line balance?
4. What is the essential requirement for mixed-model lines to be practical?
5. Why might it be difficult to develop a group technology layout?
6. In what respects is facility layout a marketing problem in services? Give an example of a service system layout designed to maximize the amount of time the customer is in the system.
7. Visit a major hotel in your area and describe the layout of its operations.
8. Describe the layout of a branch office of a bank.
9. How might you design the layout for a walk-in clinic?
10. Visit two different supermarkets. What similarities do their layouts share in common? What differences did you notice?

Solved Problems

Problem 1

A university advising office has four rooms, each dedicated to specific problems: petitions (Room A), schedule advising (Room B), grade complaints (Room C), and student counseling (Room D). The office is 80 feet long and 20 feet wide. Each room is 20 feet by 20 feet.

The present location of rooms is A, B, C, D; that is, a straight line. The load summary shows the number of contacts that each advisor in a room has with other advisors in the other rooms. Assume that all advisors are equal in this value.

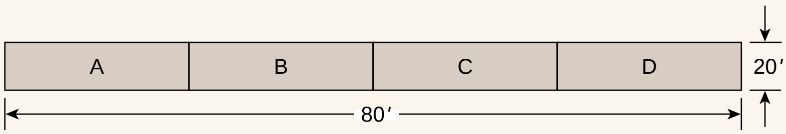
Load summary: AB = 10, AC = 20, AD = 30,
BC = 15, BD = 10, CD = 20.

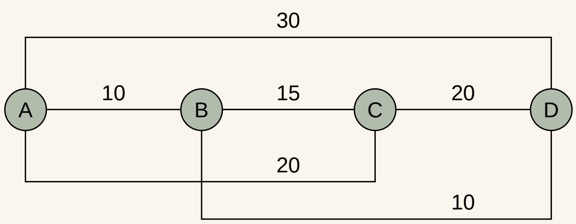
a. Evaluate this layout according to one of the methods presented in this chapter.

b. Improve the layout by exchanging functions within rooms. Show your amount of improvement using the same method as in *a*.

Solution

a. Evaluate this layout according to one of the methods in the chapter.

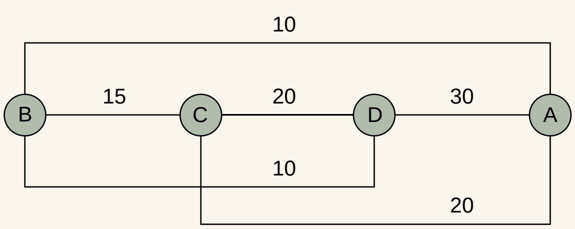




Using the material handling cost method shown in the toy company example, we obtain the following costs, assuming that every nonadjacency doubles the initial cost/unit distance:

AB = 10 × 1 = 10
AC = 20 × 2 = 40
AD = 30 × 3 = 90
BC = 15 × 1 = 15
BD = 10 × 2 = 20
CD = 20 × 1 = 20
Current cost = 195

b. Improve the layout by exchanging functions within rooms. Show your amount of improvement using the same method as in *a*. A better layout would be either BCDA or ADCB.



AB = 10 × 3 = $30
AC = 20 × 2 = 40
AD = 30 × 1 = 30
BC = 15 × 1 = 15
BD = 10 × 2 = 20
CD = 20 × 1 = 20

Improved cost = $155

Problem 2

The following tasks must be performed on an assembly line in the sequence and times specified.

Task	Task Time (seconds)	Tasks That Must Precede	Task	Task Time (seconds)	Tasks That Must Precede
A	50	—	E	20	C
B	40	—	F	25	D
C	20	A	G	10	E
D	45	C	H	35	B, F, G

a. Draw the schematic diagram.

b. What is the theoretical minimum number of stations required to meet a forecasted demand of 400 units per eight-hour day?

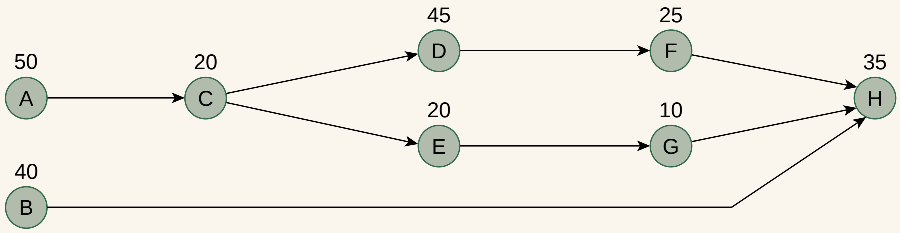
c. Use the longest-operating-time rule and balance the line in the minimum number of stations to produce 400 units per day.

d. Compute the efficiency of the line.

e. Does your solution generate any managerial concerns?

Solution

a. Draw the schematic diagram.



b. Theoretical minimum number of stations to meet D = 400 is

$$N_t = \frac{S}{T} = \frac{245 \text{ seconds}}{\left(\dfrac{60 \text{ seconds} \times 480 \text{ minutes}}{400 \text{ units}}\right)} = \frac{245}{72} = 3.4 \quad \rightarrow \quad 4 \text{ stations}$$

c. Use the longest-operating-time rule and balance the line in the minimum number of stations to produce 400 units per day.

	Task	Task Time (seconds)	Remaining Unassigned Time	Feasible Remaining Tasks
Station 1	A	50	22	C
	C	20	2	None
Station 2	D	45	27	E, F
	F	25	2	None
Station 3	B	40	32	E
	E	20	12	G
	G	10	2	None
Station 4	H	35	37	None

d. Efficiency $= \frac{S}{N_a \times T} = \frac{245}{4(72)} = 85\%$

e. Yes. Station 4 is only half as busy as the other three stations.

Problems

1. An assembly line makes two models of trucks: a Buster and a Duster. Busters take 12 minutes each and Dusters take 8 minutes each. The daily output requirement is 24 of each per day. Develop a balanced mixed-model sequence to satisfy demand.
2. The tasks and the order in which they must be performed according to their assembly requirements are shown in the following table. These are to be combined into workstations to create an assembly line.

   The assembly line operates 7½ hours per day. The output requirement is 1,000 units per day.

Task	Preceding Tasks	Time (seconds)
A	—	15
B	A	24
C	A	6
D	B	12
E	B	18
F	C	7
G	C	11
H	D	9
I	E	14
J	F, G	7
K	H, I	15
L	J, K	10

   a. What is the takt time?

   b. Balance the line based on the 1,000-unit forecast, stating which tasks would be done in each workstation.

   c. For *b* above, what is the efficiency of your line balance?

   d. After production was started, Marketing realized that they understated demand and will need to increase output to 1,100 units. What action would you take? Be specific in quantitative terms, if appropriate.

3. An assembly line operates seven hours per day and produces 420 units per day. The following tasks are required with their respective performance times and preceding tasks.

Task	Time (seconds)	Preceding Tasks
A	15	None
B	15	None
C	45	A, B
D	45	C

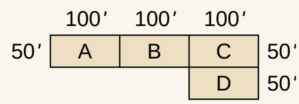
   Compute the takt time and the theoretical minimum number of workstations, and prepare an initial line configuration. Determine the efficiency of your assembly line.

4. An initial solution has been given to the following process layout problem. Given the flows described and a transportation cost of $2.00 per unit per foot, compute the total

cost for the layout. Each location is 100 feet long and 50 feet wide as shown on the figure below. Use the centers of departments for distances and compute using rectilinear distances.

Department

Department		A	B	C	D
	A	0	10	25	55
	B		0	10	5
	C			0	15
	D				0



5. An assembly line will operate eight hours per day and produce 480 units per day. The task times and precedence relationships are summarized below. Prepare an initial assembly-line configuration using the longest-operating-time rule, and determine the efficiency of your layout.

Task	Time (seconds)	Preceding Tasks
A	20	None
B	40	A
C	35	B
D	35	B
E	35	C, D

6. An assembly line is to be designed that will operate 7½ hours per day and supply a steady demand of 300 units per day. Following are the tasks and their task performance times.

Task	Preceding Tasks	Performance Time (seconds)
a	—	70
b	—	40
c	—	45
d	a	10
e	b	30
f	c	20
g	d	60
h	e	50
i	f	15
j	g	25
k	h, i	20
l	j, k	25

a. Draw the precedence diagram.
b. What is the takt time?
c. What is the theoretical minimum number of workstations?
d. Assign tasks to workstations, stating what your logic rule is.
e. What is the efficiency of your line balance?
f. Suppose demand increases by 10 percent. How would you react to this?

7. Given the following data on the task precedence relationships for an assembled product and assuming that the tasks cannot be split, what is the theoretical minimum takt time?

Task	Performance Time (minutes)	Tasks That Must Precede
A	3	—
B	6	A
C	7	A
D	5	A
E	2	A
F	4	B, C
G	5	C
H	5	D, E, F, G

a. Determine the minimum number of stations needed to meet a takt time of 10 minutes according to the "largest number of following tasks" rule.

b. Compute the efficiency of the balances achieved.

8. Simon's Mattress Factory is planning to introduce a new line of "pillow-top" mattresses. Current plans are to produce the mattresses on an assembly line. Mattresses will be built on individual platforms pulled by a chain in a track in the floor. This will allow workers to completely walk around the mattress. Tools will be suspended from the ceiling, so that there will not be a problem with tangling cords or wrapping them around the platform.

   The assembly-line process starts with the basic spring foundation and builds the mattress as it progresses down the line. There are 12 operations required, and their times and process sequence are as follows:

Operation	Time (minutes)	Tasks That Must Precede
A	1	—
B	3	A
C	4	B
D	1	B
E	5	C
F	4	D
G	1	E, F
H	2	G
I	5	G
J	3	H
K	2	I
L	3	J, K

   Tentative plans are to operate the line 7½ hours per day. Demand for the mattresses is expected to be 70 per day.

   a. Draw the schematic diagram.

   b. What is the takt time?

   c. What is the theoretical minimum number of workstations?

   d. Create a reasonably balanced assembly line.

   e. Supposing the plan was to produce these in a job shop layout. Discuss and compare the characteristics, pros, cons, and so forth of a job shop versus assembly line for this mattress production.

9. XYZ Manufacturing Company received a contract for 20,000 units of a product to be delivered in equal weekly quantities over a six-month period. XYZ works 250 days per year on a single-shift, 40-hour work week.

The table below states the tasks required and their precedence sequence and task times in seconds.

Task	Task That Must Precede	Time (seconds)
A	—	150
B	A	120
C	B	150
D	A	30
E	D	100
F	C, E	40
G	E	30
H	F, G	100

a. Develop an assembly line that meets the requirements.

b. State the takt time.

c. What is the efficiency of the line?

d. Supposing the vendor asked you to increase output by 10 percent. State specifically how you would respond to this.

10. The following tasks are to be performed on an assembly line:

Task	Time (seconds)	Tasks That Must Precede
A	20	—
B	7	A
C	20	B
D	22	B
E	15	C
F	10	D
G	16	E, F
H	8	G

The workday is 7 hours long and the demand for completed product is 750 units per day.

a. Find the takt time.

b. What is the theoretical number of workstations?

c. Draw the precedence diagram.

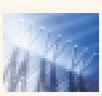
d. Balance the line using the longest-operating-time rule.

e. What is the efficiency of the line balanced as in *d*?

f. Suppose that demand rose from 750 per day to 800 units per day. What would you do?

g. Suppose that demand rose from 750 per day to 1,000 units per day. What would you do?

Internet Exercise



Using PLANT and LAYOUT as suggested key words, search the Web to identify and describe in detail the plant layout for an individual company. As an alternative, go to the McGraw-Hill Operations Management homepage at http://www.mhhe.com/pom and take a plant tour of a company and describe the physical layout of the operation.

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Case

Community Hospital

In 1983, Community Hospital, which had served the downtown area of a large West Coast city for more than 25 years, closed and then built a new hospital in a thinly populated area about 30 miles west of the city. The new hospital, also named Community Hospital, was located on a parcel of land owned by the original hospital for many years.

This new hospital, which opened October 1, 1983, is a four-story structure that includes all the latest innovations in health-care technology. The first floor houses the emergency departments; intensive care unit; operating room; radiology, laboratory, and therapy departments; pharmacy; housekeeping and maintenance facilities and supplies, as well as other supportive operations. All administrative offices, such as the business office, medical records department, special services, and so forth, are located on the second floor, as are the cafeteria and food service facilities. The two upper floors contain patient rooms divided into surgical, medical, pediatric, and obstetric units.

Community Hospital has a total capacity of 177 beds assigned as follows:

Unit	Number of Beds
Surgical	45
Medical	65
Pediatrics	35
Obstetrics	20
Intensive care	12

For the first six months of the hospital's operation, things were rather chaotic for the administrator, Sam Jones. All his time was occupied with the multitude of activities that go along with starting a new facility, such as seeing that malfunctioning equipment was repaired, arranging for new staff to be hired and trained, establishing procedures and schedules, making necessary purchasing decisions, and attending endless conferences and meetings.

All during this period, Mr. Jones had been getting some rather disturbing reports from his controller, Bob Cash, regarding Community Hospital's financial situation. But he decided that these financial matters would simply have to wait until things had settled down.

Finally, in April, Mr. Jones asked Mr. Cash to prepare a comprehensive report on the hospital's financial position and to make a presentation with his new assistant administrator, Tim Newman, who had recently received a degree in hospital administration.

In his report, Mr. Cash stated: "As you both know, we have been running at an operating cash deficit since we opened last October. We expected, of course, to be losing money at the start until we were able to establish ourselves in the community and draw in patients. We certainly were right. During our first month, we lost almost $221,000. Last month, in March, we lost $58,000.

"The reason, of course, is pretty straightforward. Our income is directly related to our patient census (i.e., patient load). On the other hand, our expenses are fixed and are running at about $235,000 a month for salaries and wages, $75,000 a month for supplies and equipment, and another $10,000 a month in interest charges. Our accumulated operating deficit for the six months we've been here totals $715,000, which we've covered with our bank line of credit. I suppose we can continue to borrow for another couple of months, but after that I don't know what we're going to do."

Mr. Jones replied, "As you said, Bob, we did expect to be losing money in the beginning, but I never expected the loss to go on for six months or to accumulate to almost three-quarters of a million dollars. Well, at least last month was a lot better than the first month. Do you have any figures showing the month-to-month trend?"

Bob Cash laid the following worksheet on the table:

COMMUNITY HOSPITAL

Six-Month Operating Statement October 1983–March 1984 (in thousands of dollars)

	1983			**1984**			
	October	**November**	**December**	**January**	**February**	**March**	**Total**
Income	$ 101	$ 163	$ 199	$ 235	$ 245	$ 262	$ 1,205
Expenses (excluding interest):							
Salaries, wages	232	233	239	235	235	235	1,410
Supplies, other	80	73	74	75	73	75	450
Total	312	306	313	310	309	310	1,860
Interest	10	10	10	10	10	10	60
Operating loss	$(221)	$(153)	($124)	($ 85)	($ 74)	($ 58)	($ 715)
Average daily census	42	68	83	98	102	109	
Occupancy	24%	38%	47%	55%	58%	62%	

Questions

1. Evaluate the situation at Community Hospital with respect to trends in daily patient census, occupancy rate, and income.
2. Has there been any change in revenue per patient-day over the six-month period (assuming a 30-day month)?
3. At what capacity level will the hospital achieve breakeven?
4. What questions might we raise about the constant level of salaries and supplies relative to past and future operations?

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