CHAPTER 10

Facility Layout

Before studying this chapter you should know or, if necessary, review

1. The Hawthorne studies and human relations movement, Chapter 1, p. 14.
2. Types of operations and their characteristics, Chapter 3, pp. 66–69.
3. The load–distance model for location planning, Chapter 9, pp. 334–338.
4. Measuring rectilinear distance, Chapter 9, p. 335.

LEARNING OBJECTIVES

After studying this chapter you should be able to

1. Define layout planning and explain its importance.
2. Identify and describe different types of layouts.
3. Compare process layouts and product layouts.
4. Describe the steps involved in designing a process layout.
5. Describe the steps involved in designing a product layout.
6. Explain the advantages of hybrid layouts.
7. Explain the meaning of group technology (cell) layouts.

CHAPTER OUTLINE

WHAT'S IN OM FOR ME?

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INTERNET CHALLENGE EDS Office Supplies, Inc.

EDS is a national distributor of office supplies that delivers goods to department and specialty stores. It is planning to build a large distribution center in your state and is analyzing different location sites. You have been assigned the task of selecting the major city in your state that you think should be the site of the new distribution center. Here are some facts to consider. At present EDS has no other distribution center in your state. The goal is to locate in a major city that has easy access to major roadways; this will enable EDS to reach other destinations in the state. Although your decision will be subjective, be prepared to justify it. Go to the Internet to find a map of your state. Analyze roadways, distances, and access to other locations. Then use the Internet to get other information, such as traffic patterns, populations, and other geographic factors. Decide on the best location for the EDS distribution center and explain your decision.

On-line Resources

Companion Website www.wiley.com/college/reid

- Take interactive *practice quizzes* to assess your knowledge and help you study in a dynamic way
- Review *PowerPoint slides* or print slides for notetaking
- Download *Excel Templates* to use for problem solving
- Access the *Virtual Company: Cruise International, Inc.*
- Find links to *Company Tours* for this chapter
  Northeast Knitting Mills
  Coppley Apparel Group
- Find links for *Additional Web Resources* for this chapter
  The Association for Manufacturing Excellence, *www.ame.org*
  APICS—The Educational Society of Resource Management, *www.apics.org*

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Wouldn't it be frustrating if every time you wanted to get a cup of coffee you had to go to one end of the kitchen to get a cup, then to another end to get the coffee, and then to a third end to get a spoon? What if when you wanted to study you had to go to one room to get your backpack, then to another room to get your books, and then to a third room to get your writing material? What if when you went to your college cafeteria for lunch you had to go to one area of the cafeteria for a tray, then to another area for the plates, and then to yet another area for the utensils? You would be experiencing wasted energy and time, as well as disorganization due to poor layout planning. As you can see from these examples, your experience would be frustrating. Now imagine the same kinds of problems in a company and you will appreciate the consequences of poor layout planning.

Proper layout planning cuts costs by eliminating unnecessary steps and increasing efficiency. However, a good layout plan can do much more for a company by improving worker attitude and creating a positive organizational climate. Consider the SAS Institute, a software company known for having its facilities arranged for comfort and enjoyment of their employees. The company has on-site child care facilities, a cafeteria with a pianist, a gym with a swimming pool, horseback riding, and a health clinic. The facility layout was designed to be aesthetically pleasing to the employees. The consequences have been high productivity and very low turnover. For this reason, SAS is regularly on *Fortune* magazine's list of top companies to work for.

In this chapter you will learn why layout planning is important. You will also learn about different types of layouts and how to design them so as to maximize efficiency.

WHAT IS LAYOUT PLANNING?

Layout planning is deciding on the best physical arrangement of all resources that consume space within a facility. These resources might include a desk, a work center, a cabinet, a person, an entire office, or even a department. Decisions about the arrangement of resources in a business are not made only when a new facility is being designed; they are made any time there is a change in the arrangement of resources, such as a new worker being added, a machine being moved, or a change in procedure being implemented. Also, layout planning is performed any time there is an expansion in the facility or a space reduction.

▶ **Layout planning**
Deciding on the best physical arrangement of all resources that consume space within a facility.

The arrangement of resources in a facility can significantly affect the productivity of a business. As you saw in the opening examples, a lot of wasted time, energy, and confusion can result from a poor layout. There are also other reasons layout planning is important. In many work environments, such as office settings, face-to-face interaction between workers is important. Proper layout planning can be critical in building good working relationships, increasing the flow of information, and improving communication. Similarly, in retail organizations layout can affect sales by promoting visibility of key items and contributing to customer satisfaction and convenience. As you can see, layout planning affects many areas of a business, and its importance should not be underestimated.

▶ **Intermittent processing systems** Systems used to produce low volumes of many different products.

▶ **Repetitive processing systems** Systems used to produce high volumes of a few standardized products.

In Chapter 3 we learned about different types of operations based on degree of product standardization and volume of output. We learned that there are two broad categories of operations: intermittent and repetitive processing systems. **Intermittent processing systems** are seen in organizations that produce a large variety of different products, each in low volume. An example is a typical job shop. On the other hand, **repetitive processing systems** are used to produce a small variety of standardized products in high volume. An example is an assembly line. As we will see in this chapter, the nature of a company's operations is directly related to the type of layout it uses.

TYPES OF LAYOUTS

There are four basic layout types: *process*, *product*, *hybrid*, and *fixed position*. In this section we look at the basic characteristics of each of these types. Then we examine the details of designing some of the main types.

Process Layouts

▶ **Process layouts** Layouts that group resources based on similar processes or functions.

Process layouts are layouts that group resources based on similar processes or functions. This type of layout is seen in companies with intermittent processing systems. You would see a process layout in environments in which a large variety of items are produced in a low volume. Since many different items are produced, each with unique processing requirements, it is not possible to dedicate an entire facility to each item. It is more efficient to group resources based on their function. The products are then moved from one resource to another, based on their unique needs.

Courtesy The Kroger Co

Process layouts arrange items by type as seen in this grocery store.

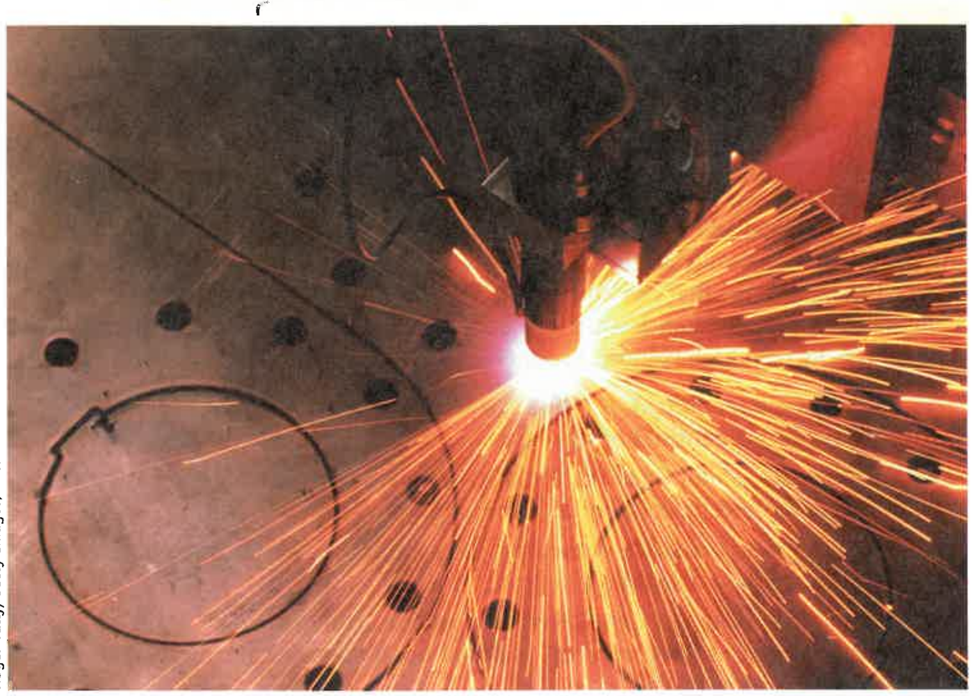
The challenge in process layouts is to arrange resources to maximize efficiency and minimize waste of movement. If the process layout has not been designed properly, many products will have to be moved long distances, often on a daily basis. This type of movement adds nothing to the value of the product and contributes to waste. Any pair of work centers that have a large number of goods moved between them should be placed in close proximity to each other. However, this often means that some other work center will have to be moved out of the way. The process layout problem thus can become quite complex, since we are not only looking at the relationship of two resources at one time but at all our resources simultaneously.

Process layouts are very common. A hospital is an example of process layout. Departments are grouped based on their function, such as cardiology, radiology, laboratory, oncology, and pediatrics. The patient, the product in this case, is moved between departments based on his or her individual needs. A university is another example. Colleges and departments are grouped based on their function. You, the student, move between departments based on the unique program you have chosen. Another example is a metalworking shop, where resources such as drills, welding, grinding, and painting are each grouped based on the function they perform. Other examples include a printing facility that prints books, magazines, and newspapers, or a bakery that makes many different baked goods.

Recall that process layouts are designed to produce many different items, often to customer specifications. To achieve this goal they have certain unique characteristics:

1. *Resources used are general purpose.* The resources in a process layout need to be capable of producing many different products.
2. *Facilities are less capital intensive.* Process layouts have less automation, which is typically devoted to the production of one product.
3. *Facilities are more labor intensive.* Process layouts typically rely on higher-skilled workers who can perform different functions.
4. *Resources have greater flexibility.* Process layouts need to have the ability to easily add or delete products from their existing product line, depending on market demands.
5. *Processing rates are slower.* Process layouts produce many different products, and there is greater movement between workstations. Consequently, it takes longer to produce a product.
6. *Material handling costs are higher.* It costs more to move goods from one process to another.
7. *Scheduling resources is more challenging.* Scheduling equipment and machines is particularly important in this environment. If it is not done properly, long waiting lines can form in front of some work centers while others remain idle.
8. *Space requirements are higher.* This type of layout needs more space due to higher inventory storage needs.

Improper design of process layouts can result in costly inefficiencies, such as high material handling costs. A good design can help bring order to an environment that might otherwise be very chaotic.



Roger Tully/Getty Images, Inc.

A tool and die manufacturing plant is an example of a process layout.

LINKS TO PRACTICE

Wal-Mart Stores, Inc.
www.walmart.com

THOMAS ENGSTROM/
Bloomberg News/Landov

The importance of a good process layout is illustrated by Wal-Mart, a company that has revolutionized retailing. A great deal of thought and analysis went into designing the layout of the Wal-Mart facilities. Most Wal-Mart locations have the same layout to provide predictability and comfort to customers. As in most retail operations, the merchandise is grouped by category. For example, all shoes are grouped in one location, as are clothing items, stationery, and snack items. However, Wal-Mart layouts provide for maximum use of floor space. For example, the layouts are designed with multiple narrow aisles as opposed to a smaller number of wide aisles. The reason is to maximize customer exposure to merchandise. Also, Wal-Mart makes maximum use of height to store inventory and give product visibility to customers. These are some of the reasons Wal-Mart is the world's largest retailer today.

Product Layouts

▶ **Product layouts** Layouts that arrange resources in sequence to allow for an efficient buildup of the product.

Product layouts are layouts that arrange resources in a straight-line fashion to promote efficient production. They are called product layouts because all resources are arranged to meet the production needs of the product. This type of layout is used by companies that have repetitive processing systems and produce one or a few standardized products in large volume.

Examples of product layouts are seen on assembly lines, in cafeterias, or even at a car wash. In product layouts the material moves continuously and uniformly through a series of workstations until the product is completed. The challenge in designing product layouts is to arrange workstations in sequence and designate the jobs that will be performed by each station in order to produce the product in the most efficient way possible. Operations managers must decide exactly what tasks will be performed by every workstation in the sequence. They need to consider the logical order in which jobs should be done. For example, at a car wash you cannot perform drying before you have performed washing. Managers also need to consider how fast production occurs and how many units can be processed through the system. The faster production occurs, the more units that can be processed through the system.

Remember that product layouts are designed to produce one type or just a few types of products in high volume. Product layouts have the following characteristics:

1. *Resources are specialized.* Product layouts use specialized resources designed to produce large quantities of a product.
2. *Facilities are capital intensive.* Product layouts make heavy use of automation, which is specifically designed to increase production.
3. *Processing rates are faster.* Processing rates are fast, as all resources are arranged in sequence for efficient production.
4. *Material handling costs are lower.* Due to the arrangement of work centers in close proximity to one another, material handling costs are significantly lower than for process layouts.

Product layouts arrange resources in a line fashion to promote efficiency. Here workers at See's Candies plant in San Francisco prepare 4-pound boxes of chocolates for Valentine's Day.

A cafeteria line is a good example of a product layout.

5. *Space requirements for inventory storage are lower.* Product layouts have much faster processing rates and less need for inventory storage.
6. *Flexibility is low relative to the market.* Because all facilities and resources are specialized, product layouts are locked into producing one type of product. They cannot easily add or delete products from the existing product line.

The characteristic differences between process and product layouts are shown in Table 10-1.

TABLE 10-1

Characteristics of Process and Product Layouts

Process Layouts	Product Layouts
Able to produce a large number of different products.	Able to produce a small number of products efficiently.
Resources used are general purpose.	Resources used are specialized.
Facilities are more labor intensive.	Facilities are more capital intensive.
Greater flexibility relative to the market.	Low flexibility relative to the market.
Slower processing rates.	Processing rates are faster.
High material handling costs.	Lower material handling costs.
Higher space requirements.	Lower space requirements.

LINKS TO PRACTICE

Toyota Motor Corporation
www.toyota.com


TOSHIFUMI KITAMURA/AFP/Getty Images, Inc.

The importance of an efficient product layout can be seen at the Toyota Motor Corporation, the leader of just-in-time production. Toyota had pioneered the pull production system in the 1970s, which has been widely used in practice. The work centers are arranged in a line fashion and are in close proximity to one another, allowing easy transfer of work between stations. On the production line, a worker with any problem (e.g., a product defect or a malfunctioning machine) can pull a cord that summons a team leader to address the problem. The line has been designed so that workers can easily communicate their needs to one another. Upstream workers can respond to "pull" signals from workers downstream who require orders of goods. Also, the layout of the facility is designed so that workers can see each other, as visibility of the operation is considered highly important. Toyota's system is focused on eliminating waste from every aspect of the operation and is the factor that has contributed to Toyota's large success.

Hybrid Layouts

▶ **Hybrid layouts**
Layouts that combine characteristics of process and product layouts.

Hybrid layouts combine aspects of both process and product layouts. This is the case in facilities where part of the operation is performed using an intermittent processing system and another part is performed using a continuous processing system. For example, Winnebago, which makes mobile campers, manufactures the vehicle itself as well as the curtains and bedspreads that go into the camper. The vehicles are produced on a typical assembly line, whereas the curtains and bedspreads are made in a fabrication shop that uses a process layout. Hybrid layouts are very common. Often, some elements of the operation call for the production of standardized parts, which can be produced more efficiently in a product layout, whereas other parts need to be made individually in a process layout.

Hybrid layouts are often created in an attempt to bring the efficiencies of a product layout to a process layout environment. To develop a hybrid layout, we can try to identify parts of the process layout operation that can be standardized and produce them in a product layout format. One example of this is called **group technology (GT) or cell layouts**. First, families of products that are similar in their processing characteristics and resource requirements are identified. Managers can then create **cells**, or small product layouts, that are dedicated to the production of these families of products. This approach brings greater efficiency to the process layout environment. Later in the chapter we will learn more about group technology.

▶ **Group technology (GT) or cell layouts**
Hybrid layouts that create groups of products based on similar processing requirements.

Other examples of hybrid layouts can be seen in everyday life. For example, retail stores and grocery stores use hybrid layouts. In these environments, goods such as dairy items, meat, or produce are stored based on their function. From that standpoint these are process layouts. However, the layout is also designed to consider a path or sequence of purchases in a straight-line fashion, making it similar to a product layout. For example, pasta is stored immediately following spaghetti sauce.

Fixed-Position Layouts

A **fixed-position layout** is used when the product is large and cannot be moved due to its size. All the resources for producing the product—including equipment, labor, tools, and all other resources—have to be brought to the site where the product is located. Examples of fixed-position layouts include building construction, dam or bridge construction, shipbuilding, or large aircraft manufacture. The challenge with a fixed-position layout is scheduling different work crews and jobs and managing the project. Project management is discussed more fully in Chapter 16.

Fixed-position layout
A layout in which the product cannot be moved due to its size and all the resources have to come to the production site.

DESIGNING PROCESS LAYOUTS

We have mentioned that the objective in designing process layouts is to place resources close together based on the need for proximity. This need could stem from the number of trips that are made between these resources or from other factors, such as sharing of information and communication.

There are three steps in designing process layouts:

Step 1 Gather information.

Step 2 Develop a block plan or schematic of the layout.

Step 3 Develop a detailed layout.

Next we look at how each of these steps is performed.

Step 1: Gather Information

The first step is to collect information that will be used to design an initial layout. Several kinds of information are needed.

Identify Space Needed The first piece of information to be collected is the amount of space needed for each of the organization's key resources. At this stage, managers generally focus on larger resources, such as departments and work centers. Operations managers must identify the space requirements of each department relative to their capacity needs, such as size of equipment and number of employees, as well as circulation room, such as aisles.

EXAMPLE 10.1

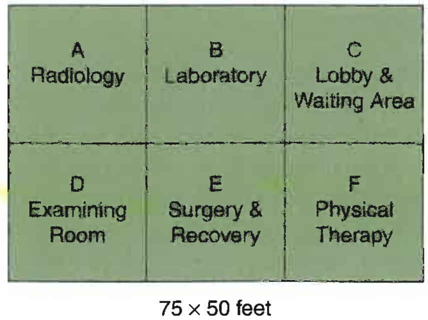
Recovery First Sports Medicine Clinic: Developing a Block Plan

Recovery First Sports Medicine Clinic is an outpatient medical facility that provides a variety of medical services to patients suffering from sports injuries. The services include exams and X-rays, physical therapy, and outpatient surgery. The departments housed in the medical facility and their exact space requirements in square feet are shown here:

Department	Area Needed (square feet)
A. Radiology	400
B. Laboratory	300
C. Lobby and waiting area	300
D. Examining rooms	800
E. Surgery and recovery	900
F. Physical therapy	1050
Total	**3750**

FIGURE 10-1

Block plan for Recovery First



▶ **Block plan**
Schematic showing the placement of resources in a facility.

Identify Available Space The available space of a facility is best seen by using a **block plan,** a schematic that shows the placement of departments in a facility. Using a block plan, we can visualize the available space and evaluate whether we can meet space needs. The current block plan for Recovery First is shown in Figure 10-1. The facility is 75 feet long by 50 feet wide, meaning that there are 3750 square feet of available space. The available space meets our total space requirements, but we will have to allocate more space to some departments. The first step in designing a process layout is to determine the best location of departments relative to one another. The easiest way to do this is to divide the available space into equal sizes to determine the departments' relative location. Much later, in the detail design stage, we can give more or less space to individual departments based on need.

Identify Closeness Measures Recall that the main criterion in deciding the location of departments relative to one another is the importance of proximity between them. At this stage we need a measure of the importance of having any pair of departments in close proximity to one another. There are two simple tools that can be used for this purpose: a from–to matrix and a REL chart. Both provide measures of the importance of having any pair of resources, such as work centers or departments, close together. This information can be used to design a good layout.

▶ **From–to matrix**
Table that gives the number of trips or units of product moved between any pair of departments.

A **from–to matrix** is a table that shows the number of trips or units of product moved between any pair of departments. Table 10-2 shows the from–to matrix for Recovery First, with daily trips made between each pair of departments. The number of trips between departments can be obtained in many ways–for example, from routing slips or order forms, by performing statistical sampling to determine frequencies, or by interviewing management. Note in Table 10-2 that all entries are above the diagonal of the matrix. Remember that we are interested in the total amount of movement

TABLE 10-2

From–To Matrix for Recovery First

	Trips between Departments					
Department	**A**	**B**	**C**	**D**	**E**	**F**
A. Radiology	—	—	—	45	12	25
B. Laboratory		—	—	45	14	5
C. Lobby and waiting area			—	50	20	43
D. Examining rooms				—	—	12
E. Surgery and recovery						—
F. Physical therapy						—

between any two departments, regardless of direction. Therefore, the matrix has consolidated movements from both directions. For example, the total number of trips between departments A and D is 45. This could mean that 20 trips are being made from A to D and 25 trips from D to A. However, for our purpose here we are not concerned with the direction of the trips, but only with the *total number* of trips in order to measure the importance of having these departments close together.

Another tool that can be used to provide information about the importance of proximity is a REL chart, short for relationship chart. A **REL chart** is a tool that reflects opinions of managers with regard to the importance of having any two departments close together. It is a good tool to use when we need to consider the judgments of managers in deciding where to locate departments. This would be the case when other factors need to be considered in making a location decision, such as communication in an office setting, face-to-face contact, or customer access as in retail businesses. In these environments it is often impossible to obtain numerical values of product flow. Using a relationship chart to develop acceptable layouts is part of a classic layout technique called *systematic layout planning* (SLP). A REL chart can be used in much the same way as a from–to matrix.

REL chart
Table that reflects opinions of managers with regard to the importance of having any two departments close together.

MKT

A REL chart for Recovery First is shown in Table 10-3. The importance of having departments close together is calculated using a predetermined scale, which is shown with the table. Values in the chart can be obtained by interviewing management and staff.

Finally, in addition to considering closeness information, a company needs to take into account other information when making layout decisions. It is very common not to be able to move certain departments due to physical constraints. For example, Recovery First has decided not to move department C, the lobby and waiting area, because it is closest to the parking lot.

Now that we have collected all the needed information, let's move to the next step in designing a process layout.

TABLE 10-3

REL Chart for Recovery First

Closeness Rating between Departments

Department	A	B	C	D	E	F
A. Radiology	—	U	U	O	A(2)	O
B. Laboratory		—	U	O	I(3)	U
C. Lobby and waiting area			—	E(1)	X(4)	I(1)
D. Examining rooms				—	O	I(1)
E. Surgery and recovery						O
F. Physical therapy						—

Explanation of Rating Codes

Rating	Definition	Code	Meaning
A	Absolutely necessary	1	Patient convenience
E	Especially important	2	Sharing of medical staff
I	Important	3	Access to equipment
O	Ordinary closeness	4	Patient privacy
U	Unimportant		
X	Undesirable		

Step 2: Develop a Block Plan

The next step in the layout planning process is to develop a new block plan or a better block plan than the one already in existence. A block plan can be developed either by trial and error or by choosing from a variety of decision-support tools. We will first use trial and error to develop a better block plan for Recovery First. When the layout problem is small in scope, trial and error can work well. However, when the layout problem is large, it may be necessary to rely on available software. Regardless of whether you choose to use software to make your layout decisions, it is important to understand the logic behind trial and error, because decision-support tools are based on heuristics that use logic similar to that used in trial and error. To understand how the decision-support tools work, you need to understand the trial-and-error process.

Using Trial and Error Recall that the goal is to develop a layout that places departments close together that have been identified as needing close proximity by either the from–to matrix or the REL chart. Recovery First has decided to develop a layout that minimizes the number of trips made in order to improve its efficiency. We will use information in the from–to matrix in Table 10-2 to identify critical pairings of departments.

Looking at the from–to matrix, we begin by identifying pairs of departments that need to be located close together. We look for pairs of departments with a high number of trips between them. From Table 10-2 we can identify the following pairs of departments:

Departments C and D, which have 50 trips between them
Departments A and D, which have 45 trips between them
Departments B and D, which have 45 trips between them
Departments C and F, which have 43 trips between them

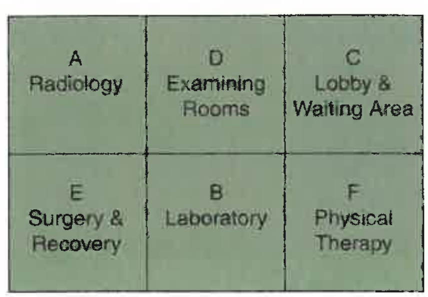
These departments have a much higher number of trips between them compared to the other department pairs. However, note that this is an arbitrary decision, one that uses judgment. If the trips are close in numerical value, the operations manager can use information from the REL chart to decide on critical pairings of departments.

Based on these criteria, we can propose the block plan shown in Figure 10-2. This plan appears to meet set criteria, but how do we know whether it is indeed better than the current layout? We need a way to measure its effectiveness quantitatively. We can do this by using the **load–distance model** that was discussed in Chapter 9. The model is shown in Table 10-4. Recall that relative locations can be compared by computing the *ld* score, which is obtained by multiplying the load for each department by the distance traveled and then summing over all the departments. The resulting score is a surrogate measure for material handling, movement, or communication. Our goal is to make the *ld* score as low as possible by reducing the distance large loads have to travel.

▶ **Load–distance model** Model used to compare the relative effectiveness of different layouts.

FIGURE 10-2

Proposed block plan for Recovery First



$$ld \text{ score for a layout} = \Sigma l_{ij} d_{ij}$$

where l_{ij} = load between departments i and j, obtained from either the from–to matrix or the REL chart

d_{ij} = distance between departments i and j, obtained from a block plan

TABLE 10-4

The Load–Distance Model

The load is the number obtained from the from–to matrix; it shows the number of trips between departments. But how do we determine the distance? We can obtain the distance from the block plan. Because the size of each block is the same, we do not need to measure the distance in feet. Rather, to keep it simple we can use one block as a measure of distance. To measure the distance between departments, we typically use *rectilinear distance*, which we studied in Chapter 9. Remember that the **rectilinear distance** between any two locations is the shortest distance using only north–south and east–west movements. Therefore, from our proposed block plan we can see that the distance between departments A and D is one block unit. Between A and C the distance is two block units, and between A and F it is three block units. Using this logic, let's compute the load–distance score for the current and proposed layouts and decide which layout is better.

▶ **Rectilinear distance** The shortest distance between two locations using north–south and east–west movements.

Table 10-5 shows computations of *ld* scores for both the current and proposed layouts for Recovery First. We can see that the proposed layout is better than the current one, as it has a lower *ld* score. In fact, the proposed layout is an almost 30 percent improvement over the current layout. To get the actual distance in feet, we could have

TABLE 10-5

ld Score Computations for Current and Proposed Layouts for Recovery First

		Current Layout		Proposed Layout	
Departments	Number of Trips (obtained from from–to matrix) *l*	Distance (obtained from current block plan) *d*	Load–Distance Score *ld*	Distance (obtained from proposed block plan) *d*	Load–Distance Score *ld*
A and D	45	1	45	1	45
A and E	12	2	24	1	12
A and F	25	3	75	3	75
B and D	45	2	90	1	45
B and E	14	1	14	1	14
B and F	5	2	10	1	5
C and D	50	3	150	1	50
C and E	20	2	40	3	60
C and F	43	1	43	1	43
D and F	12	2	24	2	24
		Total	**515**		**373**

multiplied the distance in the figure by 25, as each block is 25 feet long. However, multiplying both sides by 25 would not change their relative relationship.

The solution to the layout problem for Recovery First can also be solved using a spreadsheet, as shown.

	A	B	C	D	E	F	G
1							
2	**Block Layout for Recovery First Clinic**						
3							
4	**Existing Layout**				**Proposed Layout**		
5	A	B	C		A	D	C
6	D	E	F		E	B	F
7							
8				**Current Layout**		**Proposed Layout**	
9	**Departments**		**Number of Trips**	**Distance**	**Load-Distance**	**Distance**	**Load-Distance**
10	A	D	45	1	45	1	45
11	A	E	12	2	24	1	12
12	A	F	25	3	75	3	75
13	B	D	45	2	90	1	45
14	B	E	14	1	14	1	14
15	B	F	5	2	10	1	5
16	C	D	50	3	150	1	50
17	C	E	20	2	40	3	60
18	C	F	43	1	43	1	43
19	D	F	12	2	24	2	24
20				Total	**515**	Total	**373**
21							
22							
23							
24							

E10: =$C10*D10 (copied down, similar formulas for G10:G19)

E20: =SUM(E10:E19) (similar formula for G20)

Using Decision-Support Tools Using trial and error to develop a layout plan can often lead to satisfactory results. If we continued with trial and error in our example, we could find a solution that lowered the *ld* score even further. However, when dealing with layout problems of a more realistic size, we need to use decision-support tools. The reason is that the layout problem is a combinatorial problem. For a block plan of 6 departments, there are actually 6! different solutions, or 720 possible solutions. You can imagine how many layout alternatives there would be for a facility with 50 different departments.

A number of computer software packages can be used as decision-support tools in making the layout decision. Two of the most popular are **ALDEP** (automated layout design program) and **CRAFT** (computerized relative allocation of facilities technique). They are called decision-support tools because they use different heuristics to develop a solution. They do not give an optimal solution, and they consider only one criterion at a time in designing a layout. The best way to use these software packages is to consider the software solution as a starting point in developing a final layout.

▶ **ALDEP and CRAFT**
Computer software packages for designing process layouts.

ALDEP works from a REL chart. It constructs a layout within the boundaries of the facility by trying to link together departments that have either an A or an E rating in the REL chart. Remember that an A rating stands for absolutely necessary and an E rating for especially important. ALDEP uses this logic to link these departments together. The first department is selected randomly. To evaluate a layout, the computer program computes a score that is similar to the *ld* score we computed using trial and error. Depending on the starting point selected, many different layouts can be obtained.

CRAFT works differently from ALDEP. It is also a heuristic, but it uses a different logic to find a solution. CRAFT uses a from–to matrix and an existing layout as a starting point. It proceeds by making paired exchanges of departments that lead to a reduction of the *ld* score and continues in this manner until there are no more exchanges that can reduce the *ld* score. The solution with the lowest *ld* score is the final solution.

Many other sophisticated computer software packages for layout planning can be used to design office buildings, warehouses, and other large facilities. They are capable of designing layouts for multiple floors, and they can consider height for assigning storage locations, as in retail or warehousing. For example, SPACECRAFT is a modified version of CRAFT developed for designing multistory layouts. These software programs, including ALDEP and CRAFT, can work with a large number of departments of different sizes and shapes.

Step 3: Develop a Detailed Layout

The last step in designing a process layout is the development of a detailed layout design. At this stage the block plan is translated into a more realistic schematic. We begin to consider exact sizes and shapes of departments and work centers. We also focus on specific work elements, such as desks, cabinets, and machines, as well as aisles, stairways, and corridors. Operations managers can use a variety of tools in this final stage; they include drawings, three-dimensional models, and computer graphics software.

SPECIAL CASES OF PROCESS LAYOUT

A number of unique cases of process layout require special attention. In this section we look at two special cases: *warehouse layouts* and *office layouts.*

Warehouse Layouts

Warehouse layouts have the key characteristics of process layouts: products are stored based on their function, and there is movement of goods. The main difference is that movement within a warehouse is primarily between the loading/unloading dock and the areas where goods are stored. Typically, there is no movement between the storage areas themselves; the primary function of a warehouse is to provide storage space, so the only movement is inbound or outbound. Think about a warehouse that stores computer equipment and supplies. Printers might be stored in one area, keyboards in another, and ink cartridges in a third. Certainly there would be no movement between the keyboard storage area and the area where ink cartridges are stored. The movement would consist of bringing items either in or out of the warehouse.

Storage Areas of Equal Sizes The primary decision in designing warehouse layouts is to decide where to locate individual departments relative to the dock. Using the same logic we used for process layouts in general, the goal is to assign departments to locations in order to minimize the number of trips to the dock. As before, we need a from–to matrix that shows the number of trips. Since the movements are only between the departments and the dock, we simply locate the departments with the highest number of trips closest to the dock. Next, we locate the department with the second-highest number of trips in the next available space closest to the dock. We proceed in this manner until all the departments have been assigned. Example 10.2 illustrates a simple example.

Charlie Westerman/Stone/Getty Images, Inc.

In a warehouse distribution center, items are stored based on their function.

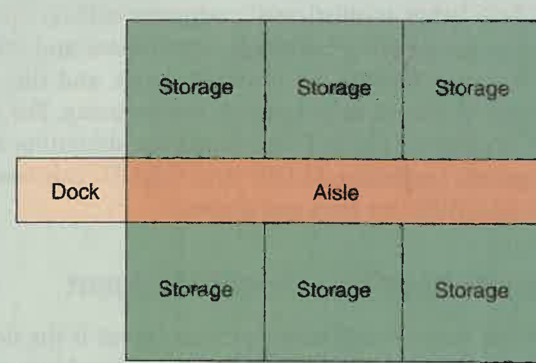
EXAMPLE 10.2

Green Grocer Makes Location Assignments

Green Grocer stores its dry goods in a nearby warehouse. The different categories of foods are stored in departments that each take up the same amount of space, shown in Figure 10-3. Given the available warehouse space and the number of trips made for each category of foods, Green Grocer needs to decide where to locate each department.

FIGURE 10-3

Warehouse storage areas for Green Grocer



Department	Food Category	Trips to and from Dock
1	Canned goods	50
2	Cereals	63
3	Condiments	35
4	Diapers and baby products	55
5	Cookies and candies	48
6	Fruit and vegetable juices	60

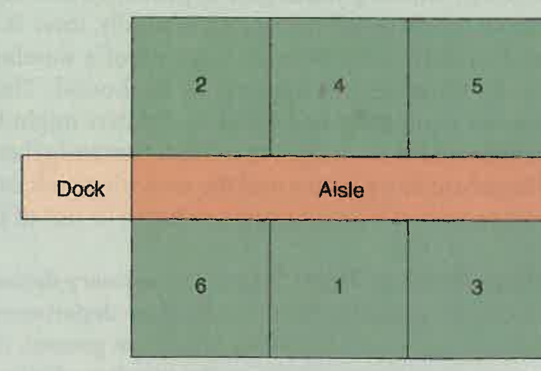
- **Before You Begin:** Remember that when solving warehouse layouts the objective is to place the departments with the highest number of trips closest to the dock.

- **Solution:**

To assign departments to specific storage areas, we progressively assign departments with the highest number of trips closest to the dock. Department 2 is placed closest because it has the highest number of trips. Next comes department 6, and so forth. Using this logic, we develop the block plan shown in Figure 10-4.

FIGURE 10-4

Block plan for Green Grocer warehouse



Storage Areas of Unequal Size In Example 10.2 all the departments required equal-sized storage areas. What would happen if the storage areas required were of different sizes? It is common for some departments to need more room than others based on the size of the product or volumes needed. Number of trips is not a good measure because it can be misleading. For example, if department A takes up 4 storage areas and makes 20 trips to the dock, it actually has fewer trips per area than department B, which takes up 1 storage area and makes 15 trips. The reason is that when trips per area are considered, department A only has 5 trips whereas B has 15.

To make location assignments when departments take up storage areas of unequal size, we need to follow these steps:

Step 1 Take the ratio of the number of trips relative to the storage area required.

Step 2 Use the ratios from Step 1 to make assignments. Assign the department with the highest ratio closest to the dock. Next, assign the department with the second-highest ratio second closest to the dock. Continue in this manner until all departments have been assigned.

Example 10.3 is another example of how this would work.

EXAMPLE 10.3

Looking Good Clothes Assigns Storage Areas

Looking Good Clothes is a clothing retailer for teenagers and young adults. The company is in the process of assigning storage areas in its warehouse in order to minimize the number of trips made to retrieve items needed. Following are the departments that need to be located, the number of trips made per week for each department, and the area needed by each department:

Department	Trips to and from Dock	Area Needed
1. Backpacks	160	2
2. Hiking boots	150	3
3. Jeans	100	1
4. T-shirts	120	1
5. Bomber jackets	270	3

The warehouse block plan is shown in Figure 10-5.

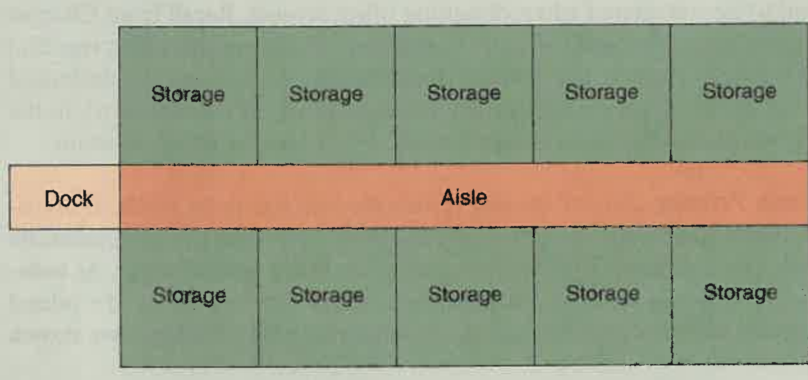


FIGURE 10-5 Warehouse storage areas for Looking Good Clothes

• **Before You Begin:** To solve this problem, follow the two-step process given for making location assignments when storage areas are of unequal size.

• **Solution:**

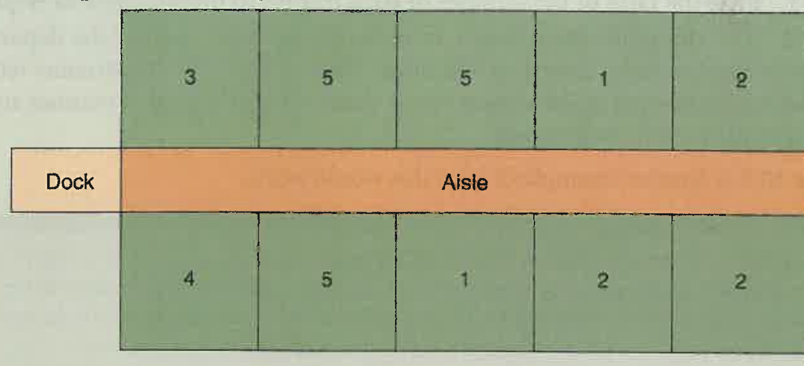
Step 1: Take the ratio of trips to the number of areas taken up by the department.

Department	Trips to and from Dock	Area Needed	Ratio of Trips to Area Needed
1. Backpacks	160	2	80
2. Hiking boots	150	3	50
3. Jeans	100	1	100
4. T-shirts	120	1	120
5. Bomber jackets	270	3	90
	Total Area	10	

Step 2: Use the ratios from Step 1 to assign departments to storage areas. These are shown in the block plan in Figure 10-6.

FIGURE 10-6

Block plan for Looking Good warehouse



Office Layouts

Office layouts are another special case of process layouts. Merely looking at the number of trips between departments or the movement of goods is not sufficient to design a good office layout because human interaction and communication are the primary factors that need to be considered when designing office layouts. Recall from Chapter 1 that an important lesson learned from the Hawthorne studies in the 1930s was that workers respond greatly to their physical environment and have many psychological needs. This information, coupled with the fact that almost half of the workforce in the United States works in an office environment, makes office layouts very important.

Proximity versus Privacy One of the key trade-offs that has to be made in an office layout is between proximity and privacy. The ability of workers to communicate and interact with one another is highly important in an office environment. As companies increasingly embrace team approaches, open office environments are valued because they provide visibility and allow workers to interact easily. Studies have shown

A properly designed office layout can significantly improve productivity.

Chuck Keeler/Stone/Getty Images, Inc.

that workers who are in close proximity to one another have greater understanding, tolerance, and trust for one another.

However, office layouts that enhance team interactions do not allow privacy. Often, employees need privacy to think and work quietly without being interrupted. Also, it may be difficult to have confidential conversations with coworkers and clients in an open office environment. When designing an office layout, these considerations must be addressed in order to enhance productivity.

Other Factors in Designing Office Environments One important consideration in designing any layout is flexibility. **Flexible layouts** remain desirable many years into the future or can be easily modified to meet changing demands. Traditional load-bearing walls provide privacy but do not provide flexibility. Partitions, on the other hand, are very flexible but do not offer privacy.

▶ **Flexible layouts** Layouts that remain desirable many years into the future or can be easily modified to meet changing demand.

Companies are becoming more creative in meeting the needs of their employees, enhancing productivity, and designing flexible layouts. One option is to use what is commonly called *office landscaping*. This entails using plants, decor, and indoor landscaping to provide natural-looking partitions and sections that allow for privacy and flexibility but still have the feel of an open office environment. In addition, the natural look of office landscaping provides a pleasant working environment.

Before You Go On

We have described several different types of layouts. By now you should know how to design process layouts and understand the unique characteristics of warehouse and office layouts. We will now learn how to design product layouts. Since process and product layouts are very different, make sure you review these differences. Before proceeding further, also review the characteristics of product layouts.

DESIGNING PRODUCT LAYOUTS

Recall that product layouts arrange resources in sequence so that the product can be made as efficiently as possible. This type of layout is used in repetitive processing systems that produce a large volume of one standardized product.

Product layouts are completely different from process layouts. In product layouts the material moves continuously and uniformly through a sequence of operations until the work is completed. The sequence of operations allows for the simultaneous performance of work. When designing product layouts, our objective is to decide on the sequence of tasks to be performed by each workstation. To accomplish this we need to consider the logical order of the tasks to be performed and the time required to perform each task. Also, we need to consider the speed of the production process, which will tell us how much time there is at each workstation to perform the assigned tasks. This entire process is called **line balancing**. Next we will go through the steps that must be followed in designing product layouts.

▶ **Line balancing** The process of assigning tasks to workstations in a product layout in order to achieve a desired output and balance the workload among stations.

Step 1: Identify Tasks and Their Immediate Predecessors

The first step in designing product layouts is to identify the tasks or work elements that must be performed in order to produce the product. We also need to determine how long each task takes to perform and which tasks must be performed in sequence. The task or tasks that must be performed immediately before another task can be done is called the task's **immediate predecessor**. We use an example to illustrate this point.

▶ **Immediate predecessor** A task that must be performed immediately before another task.

EXAMPLE 10.4

Vicki's Pizzeria and the Precedence Diagram

Vicki's Pizzeria is planning to make boxed take-out versions of its famous pepperoni, sausage, and mushroom pizza. The pizzas will be made on a small assembly line. Vicki has identified the tasks that need to be performed, the time required for each task, and each task's immediate predecessor. This information is shown here:

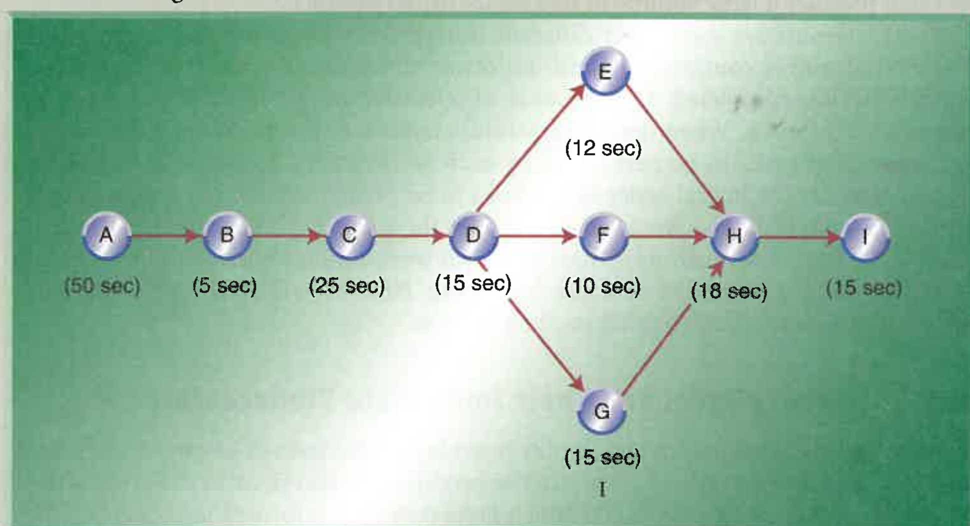
Work Element	Task Description	Immediate Predecessor	Task Time (in seconds)
A	Roll dough	None	50
B	Place on cardboard backing	A	5
C	Spread sauce	B	25
D	Sprinkle cheese	C	15
E	Add pepperoni	D	12
F	Add sausage	D	10
G	Add mushrooms	D	15
H	Shrinkwrap pizza	E, F, G	18
I	Pack in box	H	15
		Total task time	**165**

▶ **Precedence diagram** A visual representation of the precedence relationships between tasks.

Often it is helpful to have a visual representation of the precedence relationships between the tasks that need to be performed. This is called a **precedence diagram**. Figure 10-7 illustrates the precedence diagram for assembling Vicki's pizzas. The diagram is read from left to right. The circles, or nodes, represent the tasks, and the arrows, or arcs, show the connections between them. Together, they show how the tasks are connected. To find a task's immediate predecessor, follow the arrows backward from your task. In the diagram you can see that the first task that must be performed is task A. After A has been completed, B should be done. Next comes task C and then D. After task D, however, we can do either E, F, or G. However, to be able to complete task H, we must have completed all the predecessors of H—namely, E, F, and G. Finally, after all the other tasks have been completed, task I can be performed.

FIGURE 10-7

Precedence diagram for Vicki's Pizzeria



Step 2: Determine Output Rate

The next step is to determine how many units of product we wish to produce over a period of time, called the **output rate**. Then we can design a product layout that produces the desired number of units with as few work centers as possible and balance the workload at each workstation. In our example, Vicki has decided that she wishes to produce 60 pizzas per hour in order to meet her growing demand.

▶ Output rate
The number of units we wish to produce over a specific period of time.

Notice that the total task time to produce 1 pizza is 165 seconds. If Vicki wants to perform all nine work elements herself, her maximum output in 1 hour would be:

$$\text{Maximum output} = \frac{3600 \text{ seconds/hour}}{165 \text{ seconds/unit}} = 21.8 \text{ pizzas/hour}$$

If Vicki wants to produce 600 pizzas in an hour, she will have to divide the work among a number of people working simultaneously at workstations to achieve her desired output rate. Let's see what Vicki has to consider.

Step 3: Determine Cycle Time

Cycle time is the maximum amount of time each workstation has to complete its assigned tasks. Cycle time also tells us how frequently a product is completed. Recall that in product layouts work is being performed on many workstations that are arranged in sequence. At the beginning of the line, workers are carrying out the initial stages of putting the product together. At the end of the line, the last steps of production are being completed. If you were to stop the process at any one point in time, you would find products at all stages of production, from raw materials through work-in-process, as well as completed products.

▶ Cycle time
The maximum amount of time each workstation has to complete its assigned tasks.

Cycle time is directly related to the volume that can be produced. The faster the cycle time (the lower its numerical value), the greater the output. A cycle time of 50 seconds means that each workstation has 50 seconds to perform its assigned tasks and that one unit is completed every 50 seconds. By contrast, a cycle time of 100 seconds would give more time to each workstation. It also means that a product would be completed every 100 seconds. You can see that by producing a unit every 50 seconds we will produce more units at the end of the day, as opposed to producing a unit every 100 seconds. Therefore, cycle time is directly related to output.

$$\text{Output} = \frac{\text{available time}}{\text{cycle time}}$$

General Cycle Time Equation Cycle time can be computed from the preceding equation as follows:

$$\text{Cycle time} = C = \frac{\text{available time}}{\text{output}}$$

Computing Cycle Time When Output Is in Units per Hour Cycle time is generally computed in seconds per unit. Note that available time and output are measured over a period of time, such as per hour or per day. Remember that these need to be over the same time period for the computation to work. For example,

$$\text{Cycle time (seconds/unit)} = C = \frac{\text{available time (seconds/hour)}}{\text{output (units/hour)}}$$

Note that the "per hour" in the numerator cancels out the "per hour" in the denominator and the final measure is "seconds per unit."

Computing Cycle Time When Output Is in Units per Day The same type of computation would be performed if we were given the desired output in units per day:

$$\text{Cycle time (seconds/unit)} = C = \frac{\text{available time (seconds/day)}}{\text{output (units/day)}}$$

As before, the "per day" in the numerator cancels out the "per day" in the denominator and the final measure is "seconds per unit." The important thing is to use the same units in the denominator as in the numerator.

Now let's compute the cycle time for Vicki's assembly line. Vicki said that she wanted to produce 60 pizzas per hour as her desired output. We start with the general equation for cycle time. Then we substitute the specific numerical values and perform the computations:

$$\text{Cycle time (seconds/unit)} = C = \frac{\text{available time (seconds/hour)}}{\text{desired output (units/hour)}}$$

$$= \frac{60 \text{ minutes/hour} \times 60 \text{ seconds/minute}}{60 \text{ units/hour}}$$

$$= \frac{3600 \text{ seconds/hour}}{60 \text{ units/hour}}$$

$$= 60 \text{ seconds/unit}$$

Vicki needs to have a cycle time of 60 seconds per unit to produce 60 pizzas in an hour. This means that each workstation has 60 seconds to perform its task. Also, this means that 1 completed pizza will be finished every 60 seconds. After 1 hour, Vicki will have 60 pizzas.

Relationship between Minimum Cycle Time (Bottleneck) and Maximum Output What if Vicki changed her mind and wanted to produce more than 60 pizzas per hour? This would mean that her cycle time would have to be faster (its numerical value would be lower), and pizzas would be produced more frequently than every 60 seconds. Perhaps she could lower the cycle time to 55 seconds or even 50 seconds. But what is the lowest possible value for the cycle time?

Note that if Vicki lowered the cycle time below 50 seconds, there would not be enough time to do task A, which requires 50 seconds. Therefore, given the current task times, 50 seconds is the lowest cycle time Vicki's assembly line could have. Task A is the longest task and thus acts as a constraint. This is called the **bottleneck**. The bottleneck constrains the production process and determines the lowest or minimum cycle time.

▶ **Bottleneck task**
The longest task in a process.

Sometimes it is possible to reduce the bottleneck by splitting the task into smaller ones that can be done separately. For example, maybe our bottleneck task, which is rolling dough, can be divided into smaller tasks, such as placing dough on a floured board and rolling it out. However, there will always be a bottleneck. Once we eliminate one bottleneck, the next-longest task becomes the bottleneck.

The bottleneck is important because it provides the lowest limit on the cycle time. Cycle time is related to the amount of output; therefore, this minimum cycle time determines the maximum output that can be achieved given current tasks. The relationship can be derived as follows:

$$\text{Maximum output} = \frac{\text{available time}}{\text{minimum cycle time (bottleneck)}}$$

Using this equation, we can compute the maximum output Vicki can have on her assembly line given that task A (the bottleneck) takes 50 seconds:

$$\text{Maximum output} = \frac{3600 \text{ seconds/hour}}{50 \text{ seconds/unit}} = 72 \text{ units/hour, or } 72 \text{ pizzas per hour}$$

The maximum that Vicki can produce on her assembly line is 72 pizzas per hour.

Maximum versus Minimum Cycle Time We learned that the *minimum cycle time* is equal to the bottleneck, or longest, task. In our example, the minimum cycle time was 50 units per second, resulting in an output of 72 pizzas per hour. This would require that the work be spread out over multiple workstations working simultaneously. The *maximum cycle time* is equal to the sum of the task times, or 165 seconds. As we saw earlier, this would result in the production of 21.8 pizzas per hour and would require that all tasks be performed at a single workstation.

The minimum and maximum cycle times are important because they establish the range of output for the production line. In our case, the range of output is between 21.8 and 72 pizzas per hour and is dependent on the cycle time. Vicki's desired output, 60 pizzas per hour, falls within this range.

Step 4: Compute the Theoretical Minimum Number of Stations

Before we decide to assign specific tasks to workstations, it is usually helpful to compute the theoretical minimum number of stations, or *TM*. The **theoretical minimum number of stations** is the number of workstations that would be needed if the line was 100 percent efficient. Rarely do we achieve 100 percent efficiency, and often we will have more stations than the theoretical minimum. However, computing this number gives us a baseline for the number of stations we should have. The computation for the theoretical minimum number of stations is as follows:

▶ Theoretical minimum number of stations
The number of workstations needed on a line to achieve 100 percent efficiency.

$$TM = \frac{\Sigma t}{C}$$

where Σt = sum of the task times needed to complete a unit
C = cycle time

For Vicki's assembly line, the theoretical minimum number of stations (*TM*) is

$$TM = \frac{165 \text{ seconds}}{60 \text{ seconds}} = 2.75, \text{ or } 3 \text{ stations}$$

Theoretical minimum numbers of stations that end with a fraction are always rounded up because there can be no partial workstations. Notice that the theoretical minimum number of stations results in the production of daily requirements when no inefficiency exists.

Step 5: Assign Tasks to Workstations (Balance the Line)

Given the tasks we have to perform and their precedence relationships as well as the cycle time, we can now proceed to assign tasks to workstations. To do this, a number of rules can be used at this stage. We will use the *longest task time rule*, which basically states that when selecting from a group of tasks we should pick the task that takes the longest time. However, in practice a number of other rules can be used. Following are the basic steps in this process:

TABLE 10-6

Assignments of Tasks to Workstations for Vicki's Pizzeria

Workstation	Eligible Task	Task Selected	Task Time	Idle Time
1	A	A	50	10
	B	B	5	5
2	C	C	25	35
	D	D	15	20
	E, F, G	G	15	5
3	E, F	E	12	48
	F	F	10	38
	H	H	18	20
	I	I	15	5

Cycle time = 60 seconds

Steps	Procedure for Assigning Tasks to Workstations
A	Start with the first station; make a list of eligible tasks to be performed, following precedence relationships.
B	Select from the eligible task list by picking the task that takes the longest time (*longest task time rule*). If only one task is eligible, we do not need to use the rule.
C	When the cycle time has been used up at one station or no tasks can be assigned to the remaining time, start a new station.

Let's see how these steps apply to Vicki's Pizzeria. A convenient method is to make a table with columns labeled Workstation, Eligible Task, Task Selected, Task Time, and Idle Time. We can then fill in the table by following the steps we have outlined and keeping a cycle time of 60 seconds. This is shown in Table 10-6.

Step 6: Compute Efficiency, Idle Time, and Balance Delay

▶ **Efficiency**
The ratio of total productive time divided by total time, given as a percentage.

After tasks have been assigned to workstations, we should compute the efficiency of the arrangement. **Efficiency** is the ratio of total productive time divided by total time, given as a percentage:

$$\text{Efficiency (\%)} = \frac{\Sigma t}{NC}(100)$$

where Σt = sum of the task times
N = number of workstations
C = cycle time

Note that in this equation the numerator is the actual work time, whereas the denominator is the time allocated for performing tasks. To improve efficiency, we try to assign as much work to the lowest number of workstations needed to produce the volume of product desired while keeping the workloads balanced.

▶ **Balance delay**
The amount by which the line efficiency falls short of 100 percent.

Often it is helpful to compute the amount by which the efficiency of the line falls short of 100 percent. Called the **balance delay**, it is computed as follows:

$$\text{Balance delay (\%)} = 100 - \text{efficiency}$$

EXAMPLE 10.5

Computing Efficiency and Balance Delay

For Vicki's assembly line, we can compute the efficiency and balance delay:

$$\text{Efficiency (\%)} = \frac{165 \text{ seconds}}{3 \text{ stations} \times 60 \text{ seconds}}(100) = \frac{165}{180} = 91.66\%$$

$$\text{Balance delay (\%)} = 100 - 91.66 = 8.34\%$$

Other Considerations

In designing *process layouts* we went from a crude block plan to the design of a detailed layout. Similarly, many details of *product layout* design need to be addressed in addition to the ones we have discussed.

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On paced lines the product being worked on automatically moves from one station to the next.

Shape of the Line We know that product layouts arrange work centers in sequence to allow for efficient production. Even though this sequence is linear, the actual shape of the product layout usually is not one long, straight line. If it were, we would need an unusually long, straight building. Also, having a long, straight line may not be best from a productivity standpoint. Arranging the shape of the line so that workers can see and communicate with one another can improve productivity and worker satisfaction. The actual shape of the line can be an S shape, a U shape, an O, or an L. Much thought should go into the choice of an appropriate shape. For example, shapes such as U and O can store frequently used resources in the center, where they are accessible to everyone.

Paced versus Unpaced Lines Another issue to decide on is whether to have a paced or an unpaced line. On **paced lines** the product being worked on is physically attached to the line and automatically moved from one station to the next when cycle time elapses. The amount of time workers have to perform their tasks is identical to cycle time. Unpaced lines, on the other hand, allow the product to be physically removed from the line to be worked on. Workers can then vary the amount of time they spend working on the product. Storage areas for inventory are often placed between workstations, to be used when there is a delay in production at a station.

▶ **Paced line**
A system in which the product being worked on is physically attached to the line and automatically moved to the next station when the cycle time has elapsed.

The work environment has a significant impact on worker satisfaction and productivity. Some studies have found that unpaced lines lead to greater productivity when they are coupled with a good incentive program. This situation provides more autonomy and freedom for workers. However, in some environments a paced line is the only option—for example, when the product is very large and cannot be moved. This would be the case when assembling large and heavy items such as a large refrigerator or an automobile.

Number of Product Models Produced Another consideration is whether to have a single-model or a mixed-model line. A **single-model line** is designed to produce only one version of a product. In contrast, a **mixed-model line** is designed to produce many versions. For example, a single line might produce only Jeep Wranglers, whereas a mixed-model line might produce two types of Jeeps, such as the Wrangler and the Cherokee. A mixed model is more flexible, but there may be more complications with regard to scheduling and changing production from one model to the other.

▶ **Single-model line**
A line designed to produce only one version of a product.

▶ **Mixed-model line**
A line designed to produce many versions of a product.

Before You Go On

Both process and product layouts have their strengths and weaknesses. Process layouts are flexible and can produce many different kinds of products. Process layouts are less efficient than product layouts because material handling costs can create much inefficiency. Product layouts, on the other hand, are less flexible because all their resources are devoted to the production of one type of product. However, they are very efficient and create little waste. Make sure you understand these differences, because in the next section we will look at ways of combining some of the strengths of process and product layouts.

GROUP TECHNOLOGY (CELL) LAYOUTS

▶ **Group technology (GT)** Brings the efficiencies of a product layout to a process layout.

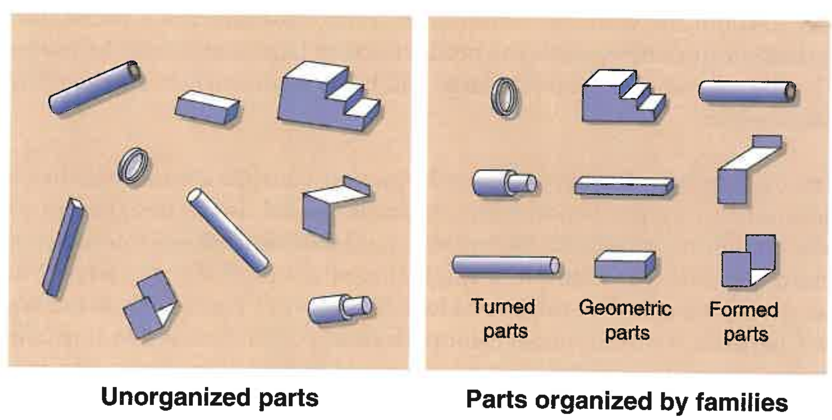
Hybrid layouts combine characteristics of both process and product layouts. They are created whenever possible in order to combine the strengths of each type of layout. One of the most popular types of hybrid layouts is **group technology (GT)** or cell layouts. Group technology has the advantage of bringing the efficiencies of a product layout to a process layout environment.

If we look at a company that produces many different products, we may find that some products are similar to each other in the way they are made and the resources they require. For example, a company may produce 500 different products. However, if we analyze how each of the products is manufactured, we may be able to create groups of products—say, one group of 150, another group of 100, and so on—that are very similar in the way they are produced. To be efficient, we could place all the resources needed for each group in a separate area, called a *cell*. The production of a group, or family, of items would be done very efficiently because all the resources required would be in close proximity. This is the goal of group technology.

Group technology is the process of creating groupings of products based on similar processing requirements. For example, Figure 10-8 shows parts that all belong to the same family. These parts are all different, but they are very similar in the way they are made. Group technology essentially creates small product layouts dedicated to the production of a group of items. Figure 10-9 shows process flows before and after the use of GT cells. The first picture is a process layout with different product routes for the many products a company produces. The second picture shows the implementation of group technology in that environment. Cells have been created for each family, and there is a much more orderly flow through the facility.

FIGURE 10-8

Unorganized and organized parts



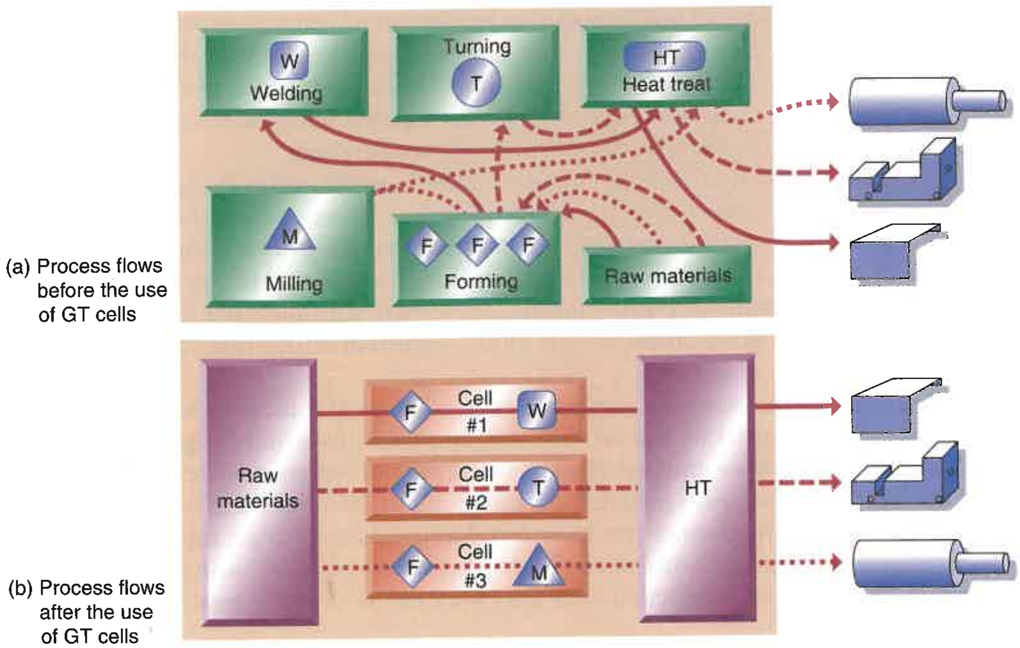


FIGURE 10-9

Process flows before and after the use of GT cells

FACILITY LAYOUT WITHIN OM: HOW IT ALL FITS TOGETHER

As you have learned in this chapter, layout decisions are directly related to issues of product design and process selection (Chapter 3). The company's process dictates the type of layout the company will have. In turn, facility layout decisions are linked with a number of other operations decisions. One such issue is that of job design, as process layouts tend to require greater worker skills than do product layouts (Chapter 11). Another issue is the degree of automation, as product layouts tend to be more capital intensive and use more automation compared to process layouts (Chapter 3). Layout decisions are also affected by implementation of just-in-time (JIT) systems, which dictate a line flow and the use of group technology (GT) cells (Chapter 7). As layout decisions specify the flow of goods through the facility, they impact all other aspects of operations management.

FACILITY LAYOUT ACROSS THE ORGANIZATION

We have seen in this chapter why layout planning is important for operations management. The production process could not run efficiently, and there would be much waste, if we did not design a proper layout for a facility. Layout planning is also important for other functions in the organization.

MKT

Marketing is highly affected by layout planning, particularly in environments where customers and clients come to the site. This is especially true in retail environments. The location and placement of goods in the facility, their visibility, and ease of access can greatly influence sales. In these types of environments the marketing of the product takes place, in part, through the layout of a facility. For example, attractive displays and product positioning in a grocery store can promote advertising and sales. Thus, it is very important for marketing to work with operations in designing the layout.

HRM

Human resources knows how the management of people can be affected by layout planning. Studies have shown that people who work and interact together on a regular basis have better working relationships. Managers need to give much thought to which groups of people need to work closely together and place them in close proximity to one another to facilitate teamwork and cooperation.

FIN

Finance is involved whenever large financial outlays and cost considerations are at stake. This is certainly true in layout planning. Redesign of layouts can be very costly, particularly if they are large scale, as when switching to an open office environment or a cell layout. Finance needs to measure the value of these investments and work with operations to create budgets. They must also understand the long-range implications of a good layout for the entire organization in order to evaluate them properly.

Everyone in the company is affected by the design of a facility's layout. Whatever organization you work at, you are somehow affected by its layout design, including the location of your office and department, the appearance of your office, and the degree of privacy you have. Also included are proximity to coworkers and other people you must interact with, whether you must travel long distances to get supplies or clerical assistance, and the aesthetics of the layout. Regardless of what business function you are in, the degree of satisfaction with your work environment is greatly dependent on the layout.

THE SUPPLY CHAIN LINK

Entities that make up a supply chain must be linked efficiently, with product flowing smoothly throughout the chain. This includes efficient shipments and deliveries between entities. Facility layout plays an important role in making sure this takes place. Arranging layouts for efficient delivery of materials to move directly to the production line is important. In locating the shipping and receiving docks, consideration must be given to the layout of the production facility and the shape of the production line to enable smooth flow between inbound and outbound shipments and the production facility. Similarly, in the retail environment delivery of products must be done in a manner that enhances sales. For example, suppliers may deliver products on display-ready pallets to directly and efficiently move the product into the retail flow, eliminating the need for unloading and stocking shelves. Arranging the facility layout to be linked to inbound and outbound shipments can greatly enhance the smooth flow of products throughout the supply chain.

Chapter Highlights

1. Layout planning is deciding on the best physical arrangement of all resources that consume space within a facility. Proper layout planning is highly important for the efficient running of a business. Otherwise, there can be much wasted time and energy, as well as confusion.

2. There are four basic types of layouts: *process, product, hybrid,* and *fixed position*. Process layouts group resources based on similar processes or functions, as in a hospital or a machine job shop. Product layouts arrange resources in straight-line fashion, as on an assembly line. Hybrid layouts combine elements of both process and product layouts in their operation. Finally, fixed-position layouts occur when the product is large and cannot be moved.

3. Process layouts provide much flexibility and allow for the production of many products with differing characteristics. Product layouts, on the other hand, provide great efficiency when producing one type of product.

4. The steps in designing a process layout are (1) gathering information about space needs, space availability, and closeness requirements of departments; (2) developing a block plan or schematic of the layout; and (3) developing a detailed layout.

5. The steps in designing a product layout are (1) identifying tasks that need to be performed and their immediate predecessors; (2) determining output rate; (3) determining cycle time; (4) computing the theoretical minimum number

of stations; (5) assigning tasks to workstations; and (6) computing efficiency, idle time, and balance delay.

6 Hybrid layouts have advantages over other layout types because they combine elements of both process and product layouts to increase efficiency.

7 An example of hybrid layouts is group technology or cell layouts. Group technology is the process of creating groupings of products based on similar processing requirements. Cells are created for each grouping of products, resulting in a more orderly flow of products through the facility.

Key Terms

layout planning 355
intermittent processing systems 356
repetitive processing systems 356
process layouts 356
product layouts 358
hybrid layouts 360
group technology (GT) or cell layouts 360
fixed-position layout 361
block plan 362
from–to matrix 362
REL chart 363
load–distance model 364
rectilinear distance 365
ALDEP and CRAFT 366
flexible layouts 371
line balancing 371
immediate predecessor 371
precedence diagram 372
output rate 373
cycle time 373
bottleneck task 374
theoretical minimum number of stations 375
efficiency 376
balance delay 376
paced line 377
single-model line 377
mixed-model line 377
group technology (GT) 378

Formula Review

1. ld score $= \Sigma l_{ij} d_{ij}$

2. Cycle time $= C = \dfrac{\text{available time}}{\text{output}}$

3. Output $= \dfrac{\text{available time}}{\text{cycle time}}$

4. Maximum output $= \dfrac{\text{available time}}{\text{minimum cycle time (bottleneck)}}$

5. $TM = \dfrac{\Sigma t}{C}$

6. Efficiency (%) $= \dfrac{\Sigma t}{NC}(100)$

7. Balance delay (%) $= 100 -$ efficiency

Solved Problems

(See student companion site for Excel template.)

• Problem 1

Jeff-Co Industries is a metalworking shop that is redesigning its layout. The from–to matrix of the numbers of trips between departments is shown in Table 10-7.

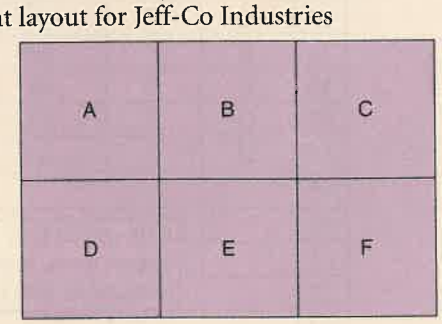
Table 10-7 From–To Matrix for Jeff-Co Industries

	Trips between Departments					
Department	**A**	**B**	**C**	**D**	**E**	**F**
A	—	10	15	—	—	50
B		—	—	20	10	20
C			—	45	—	10
D				—	—	20
E						—
F						—

The current layout is shown in Figure 10-10. Find an improved layout using trial and error. Which departments should you locate close together?

FIGURE 10-10

Current layout for Jeff-Co Industries



• *Before You Begin:*

To solve this problem, begin by identifying the departments with the highest number of trips between them from the from–to matrix in Table 10-7. Then redesign the initial layout by bringing the identified departments in close proximity to one another. Compute the *ld* scores for the initial and proposed layouts and compare.

• *Solution*

The following departments have the highest numbers of trips between them and should be located close together:

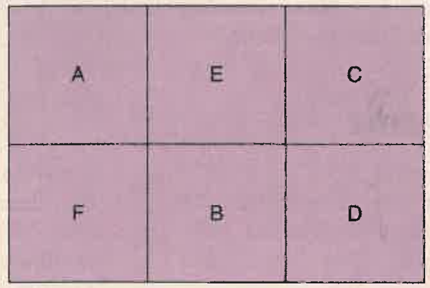
A and F, which have 50 trips between them
C and D, which have 45 trips between them

Using this as our criterion, we can construct the proposed layout shown in Figure 10-11.

We can now compute the *ld* scores for both the current and proposed layouts in order to make an evaluation. See Table 10-8 on the next page.

FIGURE 10-11

Proposed layout for Jeff-Co Industries



Based on the *ld* score, the proposed layout is an improvement of 43 percent over the current layout. This problem can also be solved using a spreadsheet. This is shown in the spreadsheet below.

	A	B	C	D	E	F	G
1							
2	**Block Layout for Jeff-Co Industries**						
3							
4	**Current Layout**				**Proposed Layout**		
5	A	B	C		A	E	C
6	D	E	F		F	B	D
7							
8				**Current Layout**		**Proposed Layout**	
9	**Departments**		**Number of Trips**	**Distance**	**Load–Distance**	**Distance**	**Load–Distance**
10	A	B	10	1	10	2	20
11	A	C	15	2	30	2	30
12	A	F	50	3	150	1	50
13	B	D	20	2	40	1	20
14	B	E	10	1	10	1	10
15	B	F	20	2	40	1	20
16	C	D	45	3	135	1	45
17	C	F	10	1	10	3	30
18	D	F	20	2	40	2	40
19				Total	**465**	Total	**265**
20							
21							
22							
23							

E10: =$C10*D10 (copied down, similar formulas for G10:G18)

E19: =SUM(E10:E18) (Similar formula for G19)

Table 10-8 *ld* Score Computations for Current and Proposed Layouts for Jeff-Co Industries

Departments	Number of Trips (obtained from from–to matrix) *l*	Current Layout: Distance (obtained from current block plan) *d*	Current Layout: Load–Distance Score *ld*	Proposed Layout: Distance (obtained from proposed block plan) *d*	Proposed Layout: Load–Distance Score *ld*
A and B	10	1	10	2	20
A and C	15	2	30	2	30
A and F	50	3	150	1	50
B and D	20	2	40	1	20
B and E	10	1	10	1	10
B and F	20	2	40	1	20
C and D	45	3	135	1	45
C and F	10	1	10	3	30
D and F	20	2	40	2	40
		Total	**465**		**265**

• Problem 2

Parachutes By Dave is a parachute production facility that assembles and packages parachutes. Table 10-9 shows the tasks required to perform the job, the times required by each task, and their immediate predecessors.

Table 10-9 Task Information for Parachutes by Dave

Work Element	Task Description	Immediate Predecessor	Task Time (sec)
A	Cast lines	None	45
B	Attach harness	A	15
C	Sew rings	A	27
D	Attach lines to chute	B	52
E	Perform safety check	C, D	7
F	Pack chute	E	18
		Total	**164 seconds**

If Dave wants to produce 50 parachutes per hour, compute the following:

(a) The appropriate cycle time
(b) The theoretical minimum number of stations
(c) Which tasks should be assigned to which workstations (using the longest task time rule)
(d) The efficiency and balance delay of your solution

• *Before You Begin:*

To solve this problem, use the steps given for designing product layouts. Notice that the sum of the task time is 164 seconds.

• *Solution*

(a) Cycle time $= C = \dfrac{\text{available time per hour}}{\text{output per hour}}$

$$= \frac{3600 \text{ seconds/hour}}{50 \text{ units/hour}} = 72 \text{ seconds/unit}$$

(b) Theoretical minimum number of stations:

$$TM = \frac{\Sigma t}{C} = \frac{164 \text{ seconds}}{72 \text{ seconds/unit}}$$

$$= 2.28 \text{ stations, or } 3 \text{ stations}$$

(c) Assigning tasks to workstations with a cycle time of 72 seconds and using the longest task time rule, we obtain the following solution:

Workstation	Eligible Task	Task Selected	Task Time	Idle Time
1	A	A	45	27
	B, C	C	27	0
2	B	B	15	57
	D	D	52	5
3	E	E	7	65
	F	F	18	47

Cycle time = 72 seconds

(d) $$\text{Efficiency (\%)} = \frac{\Sigma t}{N \times C}(100) = \frac{164}{3 \times 72}(100)$$

$$= 75.93\%$$

Balance delay (%) = 24.07%

Discussion Questions

1. Explain the importance of layout planning for a business. What are the consequences of a poor layout?
2. Explain the importance of layout planning for everyday life. How has poor layout planning affected your life?
3. Identify the four types of layouts and their characteristics.
4. Identify the steps in designing a process layout.
5. Find examples of a process layout in local businesses. Draw a picture of the locations of departments.
6. Identify the steps in designing a product layout.
7. Find examples of a product layout in local businesses. Draw a picture to show the workstations and the tasks performed.
8. Explain the concept of cycle time and how it affects output. Give an example.
9. Define group technology. Why is it important?
10. Give an example of a poor layout. Find a better solution for that layout problem.

Problems

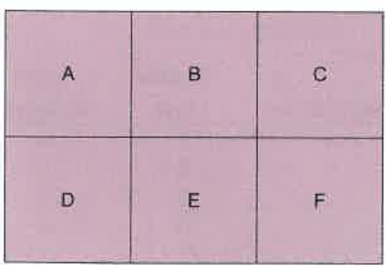
1. Fresh Foods Grocery is considering redoing its facility layout. The from–to matrix showing daily customer trips between departments is shown in Table 10-10, and their current layout is shown in Figure 10-12. Fresh Foods is considering exchanging the locations of the dry groceries department (A) and the health and beauty aids department (F). Compute the *ld* score for Fresh Foods' current and proposed layouts. Which is better?

Table 10-10 From–To Matrix for Fresh Foods

	Trips between Departments					
Department	**A**	**B**	**C**	**D**	**E**	**F**
A. Dry groceries	—	15	45	25	10	50
B. Bread		—	30	16	25	25
C. Frozen foods			—	34	15	20
D. Meats				—	40	10
E. Vegetables						20
F. Health and beauty aids						—

FIGURE 10-12

Current layout for Fresh Foods



2. Use trial and error to find a better layout for Fresh Foods Grocery in Problem 1. Compute the *ld* score and compare it to the *ld* scores computed for Fresh Foods' current and proposed layouts. Which is best?
3. Mason Machine Tools is reevaluating its facility layout. The current layout is shown in Figure 10-13 and the from–to matrix is in Table 10-11. Mason has to leave department C in its current location because relocation costs are too high. It is considering exchanging departments B and D. Evaluate the proposal by computing the *ld* score for both layouts.

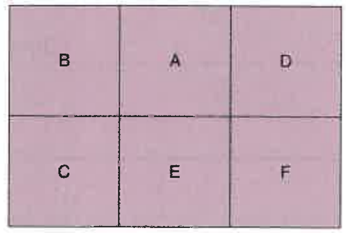


FIGURE 10-13

Current layout for Mason Machine Tools

Table 10-11 From–To Matrix for Mason Machine Tools

	Trips between Departments					
Department	**A**	**B**	**C**	**D**	**E**	**F**
A	—	5	20	5	—	8
B		—	—	30	10	10
C			—	20	15	5
D				—	—	—
E						17
F						—

4. Use trial and error to find a better layout for Mason Machine Tools in Problem 3. Compute the *ld* score and compare it to Mason's current and proposed layouts in Problem 3.
5. Gator Office Systems is comparing two layouts for the design of its office building. It has interviewed managers in order to develop the from–to matrix shown in Table 10-12. The two layouts considered are shown in Figure 10-14. Which layout do you think is better for Gator Office Systems, using the load–distance model?

Table 10-12 From–To Matrix for Gator Office Supplies

	Trips between Departments					
Department	**A**	**B**	**C**	**D**	**E**	**F**
A	—	30	—	34	50	25
B		—	—	55	10	10
C			—	—	15	5
D				—	—	—
E						30
F						—

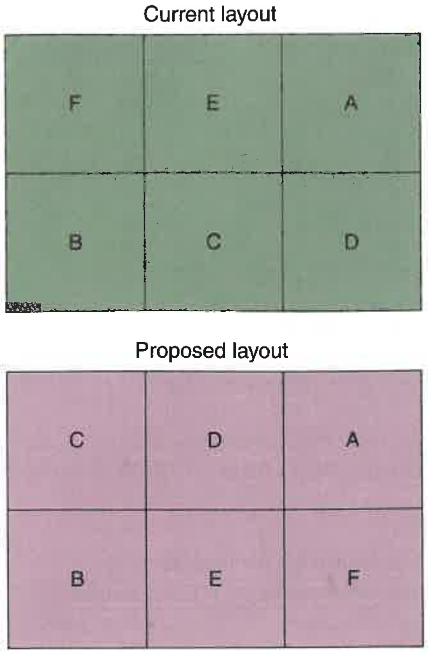


FIGURE 10-14

Current and proposed layouts for Gator Office Supplies

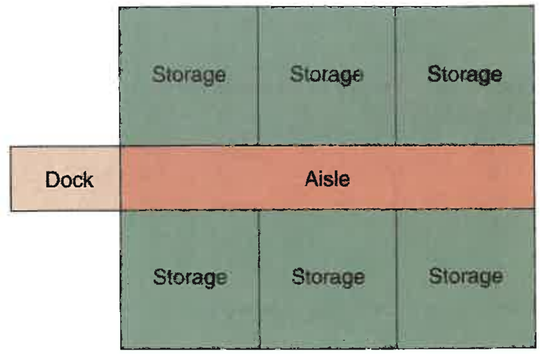


FIGURE 10-15

Warehouse storage areas for T-Shirts Unlimited

6. Use trial and error to develop a better layout for Gator Office Supplies. Which departments do you think need to be in close proximity to one another?

7. T-Shirts Unlimited is a retailer that sells every kind of T-shirt imaginable. The different types of T-shirts are stored in departments that all take up the same amount of space. Given the available warehouse space (Figure 10-15) and a from–to matrix showing the number of trips to and from each department (Table 10-13), help T-Shirts Unlimited decide where to store each type of T-shirt.

Table 10-13 From–To Matrix for T-Shirts Unlimited

Department	Category	Trips to and from Dock
1	Sports T-shirts	50
2	Men's T-shirts	63
3	Women's T-shirts	35
4	Children's T-shirts	55
5	Fashion T-shirts	48
6	Undershirts	60

8. David's Sport Supplies is a store that sells sports equipment and gear for teenagers and young adults. David's is in the process of assigning the location of storage areas in its warehouse (Figure 10-16) to minimize the number of trips made to retrieve needed items. Given here in Table 10-14 are the departments that need to be located, the number of trips made per week for each department, and the area needed by each department.

Table 10-14 Department Information for David's Sport Supplies

Department	Trips to and from Dock	Area Needed
1. Baseball equipment	160	2
2. Football gear	100	1
3. Hockey equipment	150	3
4. Basketball equipment	120	1
5. Sports clothes	270	3

9. MMS Associates is a telecommunications service provider. The company is currently redesigning its main office to accommodate six newly hired salespeople. Some of the salespeople are expected to work in teams, so office assignments are very important. Table 10-15 presents the from–to matrix showing the expected

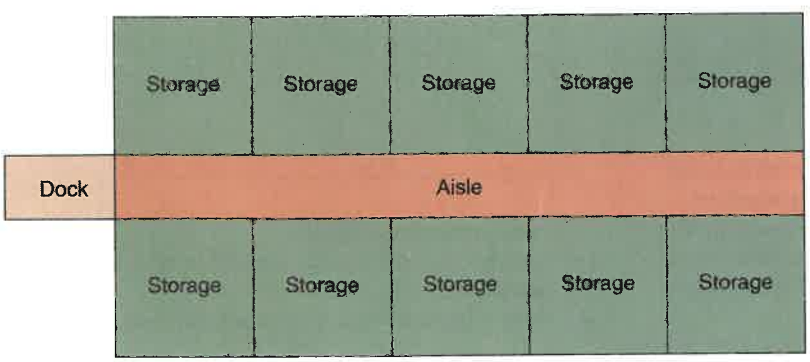


FIGURE 10-16

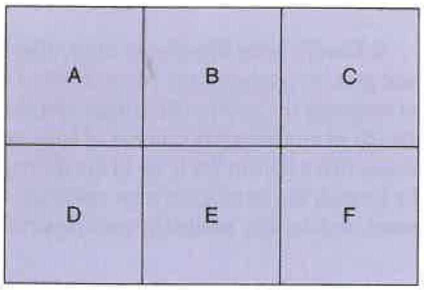
Warehouse storage areas for David's Sport Supplies frequency of contacts between members of the new sales staff. The block plan in Figure 10-17 shows the assigned office locations for the six sales members. Assume equal-sized offices and rectilinear distances. How would you evaluate the developed layout? What is the *ld* score for MMS Associates?

Table 10-15 Number of Contacts between Sales Staff

Sales Person	A	B	C	D	E	F
A	—	6	12	18	1	1
B		—	4	19	3	0
C			—	5	0	0
D				—	7	19
E					—	0
F						—

FIGURE 10-17

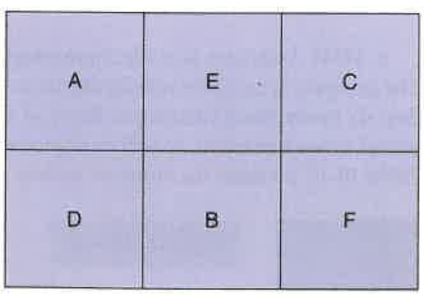
Assigned office locations for sales staff at MMS Associates



10. Michael Marc, the President of MMS Associates, is considering an alternative plan for the sales staff situation described in Problem 9. His alternative plan is shown in Figure 10-18. What is the *ld* score for this plan? How does it compare to the original plan considered in Problem 9?

FIGURE 10-18

Alternative office locations for sales staff at MMS Associates



11. Use trial and error to find a better layout for MMS Associates. Which salespeople will be your priority to keep together?

12. A manufacturing company is designing an assembly line to produce its main product. The line should be able to produce 60 units per hour. The following data in Table 10-16 give the necessary information.

Table 10-16 Task Information for Problem 12

Task	Immediate Predecessor	Task Time (sec)
A	None	35
B	A	50
C	A	21
D	B	38
E	C	25
F	D, E	58
G	F	15

(a) Which task is the bottleneck?
(b) Draw a precedence diagram for the above information.
(c) Compute the cycle time with a desired output of 60 units per hour.

13. An assembly line must be designed to produce 50 packages per hour. The following data in Table 10-17 give the necessary information.

Table 10-17 Task Information for Problem 13

Task	Immediate Predecessor	Task Time (sec)
A	None	25
B	A	60
C	B	35
D	B	45
E	B	10
F	C, D, E	50

(a) Draw a precedence diagram.
(b) Compute the cycle time (in seconds) to achieve the desired output rate.
(c) What is the theoretical minimum number of stations?
(d) Which work element should be assigned to which workstation?
(e) What are the resulting efficiency and balance delay percentages?

14. An assembly line must be designed to produce 40 containers per hour. The following data in Table 10-18 give the necessary information.

Table 10-18 Task Information for Problem 14

Task	Immediate Predecessor	Task Time (sec)
A	None	60
B	A	12
C	B	35
D	A	55
E	D	10
F	E	50
G	F, C	5

(a) Draw a precedence diagram.
(b) Compute the cycle time (in seconds) to achieve the desired output rate.
(c) What is the theoretical minimum number of stations?

(d) Which work element should be assigned to which workstation?
(e) What are the resulting efficiency and balance delay percentages?

15. The ABC Corporation is designing its new assembly line. The line will produce 50 units per hour. The tasks, their times, and their immediate predecessors are shown in Table 10-19.

Table 10-19 Task Information for ABC Corporation

Task	Immediate Predecessor	Task Time (sec)
A	None	55
B	A	30
C	A	22
D	B	35
E	B, C	50
F	C	15
G	F	5
H	G	10

(a) Which task is the bottleneck?
(b) Compute the cycle time with a desired output of 50 units per hour.
(c) Use a cycle time of 72 seconds/unit to assign tasks to workstations.
(d) Compute the theoretical minimum number of stations. Did you end up using more stations than the theoretical minimum?
(e) Compute the efficiency and balance delay of the line.

16. Kiko Teddy Bear is a manufacturer of stuffed teddy bears. Kiko would like to be able to produce 40 teddy bears per hour on its assembly line. Use the information provided in Table 10-20 to answer the questions that follow.

Table 10-20 Task Information for Kiko Teddy Bear

Work Element	Task Description	Immediate Predecessor	Task Time (sec)
A	Cut teddy bear pattern	None	90
B	Sew teddy bear cloth	A	75
C	Stuff teddy bear	B	50
D	Glue on eyes	C	20
E	Glue on nose	C	15
F	Sew on mouth	C	35
G	Attach manufacturer's label	B	15
H	Inspect and pack teddy bear	D, E, F, G	40

(a) Draw a precedence diagram.
(b) What is the cycle time?
(c) What is the theoretical minimum number of stations?
(d) Assign tasks to specific workstations using the cycle time you computed in part (b).
(e) What are the efficiency and balance delay of the line?
(f) Which task is the bottleneck?
(g) Compute the maximum output.

17. Use the longest task time rule to balance the assembly line described in Table 10-21; the line can produce 30 units per hour.

Table 10-21 Assembly-Line Task Information

Work Element	Immediate Predecessor	Task Time (sec)
A	None	25
B	A	30
C	A	15
D	A	30
E	C, D	40
F	D	20
G	B	10
H	G	15
I	E, F, H	35
J	I	25
K	J	25

(a) What is the cycle time?
(b) What is the theoretical minimum number of stations?
(c) Which work elements are assigned to which workstations?
(d) What are the resulting efficiency and balance delay percentages?

18. A dress-making operation is being designed as an assembly line. Table 10-22 shows the tasks that need to be performed, their task times, and preceding tasks. If the goal is to produce 30 dresses per hour, answer the questions that follow the table.

Table 10-22 Dress-Making Task Information

Work Element	Immediate Predecessor	Task Time (sec)
A. Cut dress body	None	30
B. Cut sleeves	None	40
C. Cut collar	None	20
D. Sew dress body	A	100
E. Sew sleeves to dress	B, D	25
F. Sew collar to dress	C, D	50
G. Hem dress	D, E, F	50
H. Package dress	G	90

(a) Compute the cycle time.
(b) Which task is the bottleneck?
(c) What is the maximum output for this line?
(d) Compute the theoretical minimum number of stations.
(e) Assign work elements to stations, using the longest task time rule.
(f) Compute the efficiency and balance delay of your assignment.

19. Table 10-23 shows the tasks required to assemble an aluminum storm door and the length of time needed to complete each task.

Table 10-23 Task Information for Problem 19

Task	Immediate Predecessor	Task Time (sec)
A	None	32
B	A	43
C	A	12
D	A	23
E	B, C, D	15
F	E	25
G	None	20
H	F, G	5

(a) Calculate the cycle time needed to produce 480 doors in an eight-hour work day.

(b) What is the minimum number of workstations that can be used on the line and still achieve the desired production rate? Balance the line and calculate its efficiency.

(c) What is the maximum output possible with these data? The minimum?

20. Use the data from Problem 19 to rebalance the line with a cycle time of 90 seconds. How does the number of workstations change? What happens to the output and the line's efficiency?

CASE: Sawhill Athletic Club (A)

Sawhill Athletic Club was an athletic facility in suburban Scottsdale, Arizona. It was designed to provide a wide range of athletic opportunities, including racquetball courts and exercise facilities. The facilities were modern, and the staff focused on providing high customer service. To provide flexibility to its members, the club had a wide range of hours of operation. The members were primarily families and young professionals who lived in the area.

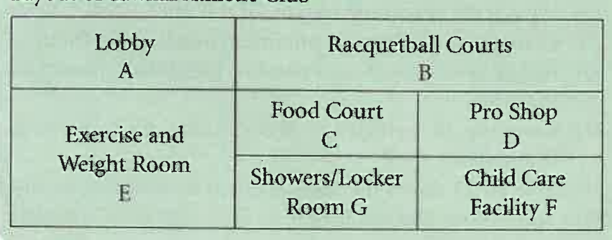
Membership at the club had been steady since it opened five years ago. To monitor the club's quality, members were often asked to fill out satisfaction surveys. Most members liked the club's attention to customer satisfaction, but many complained that the facilities did not have a good layout. They complained of having to walk long distances from one location to another, citing this as a significant inconvenience. Another complaint was that all the departments were separated with high walls, creating a "closed-in" feeling. A new athletic facility was going to be opening in the area in the near future. The owners of Sawhill thought that they had better listen to the requests of their customers in order to remain competitive.

Improving the Layout

Lauren Nicole was hired to manage Sawhill and to offer any recommendations for changing the layout of the facility. She was told to be creative and use her knowledge of facility layout design. She was even provided with a diagram of the facility and averages of daily trips made by clients between each of the departments in the facility.

Lauren began looking at the information she received, shown in the table. She noticed that all the departments were of approximately equal size except the racquetball courts and exercise facilities. These were approximately twice the size of the other departments and could not be split. All the departments were eligible to be moved. She would take that into consideration as she decided to study the information and redesign the facility. Then she would think about which walls to lower between departments to create a more open environment. Decorating would come last.

Layout of Sawhill Athletic Club



Case Questions

1. Develop an *ld* score for the current layout. What problems can you identify with the current layout?

2. Use trial and error to come up with a better layout that lowers the *ld* score. Explain the departments you thought needed to be in close proximity to one another.

3. Imagine an athletic facility such as Sawhill. What strategies would you suggest for creating an open environment?

	Number of Trips between Departments						
Department	**A**	**B**	**C**	**D**	**E**	**F**	**G**
A. Lobby	—	15	34	32	14	54	76
B. Racquetball courts		—	2	2	34	0	72
C. Food court			—	26	0	47	3
D. Pro shop				—	9	1	4
E. Exercise & weight room					—	7	74
F. Child care facility						—	57
G. Showers & locker							—

CASE: Sawhill Athletic Club (B)

Sawhill Athletic Club, an athletic facility in Scottsdale, Arizona, was known for providing a high level of customer service to its members. Member complaints were taken seriously and immediately addressed. Lauren Nicole, the new manager of Sawhill, was now faced with having to resolve another service problem.

Sawhill provided a clean towel to each member upon entering the women's or men's locker room. However, the facility had been regularly running out of clean towels for some time. Over the past month, members have complained loudly that something had to be done because they were tired of waiting for clean towels.

Currently the facility had one industrial-size washing machine and one dryer, each with a capacity to hold 20 towels. The washing machine took 20 minutes to complete a load, and the dryer took 60 minutes. Following the drying process, the towels were folded and made available to members. The folding process took approximately 1 hour for 60 towels. The washing, drying, and folding of towels was done on an almost continual basis with at least one full-time person assigned to the area. The demand averaged 60 towels per hour. The process operated as follows:

WASHING → DRYING → FOLDING

"The solution is simple. We will purchase an additional washer and dryer. That will solve the problem." Lauren said confidently.

Case Questions

1. What is the reason Sawhill is regularly running out of towels?
2. What is the cycle time of the current washing-drying-folding process? What should the cycle time be in order to meet towel demand?
3. Will purchasing an additional washer and dryer solve the problem? How will the cycle time change with an additional washer and dryer? Suggest a solution to the problem.

INTERACTIVE CASE Virtual Company

www.wiley.com/college/reid

On-line Case: Cruise International, Inc.

Assignment: *Layout Analysis at Cruise International, Inc.* Your next assignment will be with the Cruise Director, Jacqueline Downs. She is concerned that passengers start their cruise vacation in a good frame of mind. Therefore, she is quite concerned about the embarkation process and wants to make sure that guests are processed as quickly and efficiently as possible. Jacqueline wants you to examine the current embarkation process. Determine where potential waiting occurs for the guests, 5 and determine whether there might be a better layout for the embarkation process. This assignment will enhace your knowledge of the material in Chapter 10 of your textbook while preparing you for future assignments.

To access the Web site:

- Go to **www.wiley.com/college/reid**
- Click **Student Companion Site**
- Click **Virtual Company**
- Click **Consulting Assignments**
- Click **Layout Analysis at CII**

INTERNET CHALLENGE DJ and Associates, Inc.

The law firm of DJ and Associates has just moved into a new facility. The spacious reception space has room for three receptionists and a client waiting area. The law firm has hired you to help with the layout of the reception area. It has given you a budget of $15,000 and asked you to purchase furniture for the reception area that will fit into the layout, given certain constraints.

The reception area is 50 feet long by 20 feet wide. The client waiting area is 400 square feet, leaving 600 square feet for the three receptionists, their desks, chairs, file cabinets, and aisle room. The furniture for the client waiting area has been purchased. Your job is to purchase furniture for the receptionists. For each receptionist you are to purchase a desk with two chairs and two large file cabinets that will fit the constraints of the room and your budget. Since appearance is an important factor, the desks must be made of a high-grade wood. Also, there must be at least 5 feet of walking space between desks.

Use the Internet to carry out your assignment. Find Web sites for commercial office furniture sellers and browse sites for the specific furniture you need, checking dimensions and prices. Finally, come up with a plan of purchase and suggestions for a layout. It may be a good idea to read up on office layouts to get suggestions. The firm is considering hiring you for future work, so you want to develop a good plan that might include additional suggestions that were not asked for.

On-line Resources

WILEY PLUS

Companion Website www.wiley.com/college/reid

- Take interactive *practice quizzes* to assess your knowledge and help you study in a dynamic way
- Review *PowerPoint slides* or print slides for notetaking
- Download *Excel Templates* to use for problem solving
- Access the *Virtual Company: Cruise International, Inc.*
- Find links to *Company Tours* for this chapter
  - Thomson-Shore, Inc.
  - Konica Corporation
- Find links for *Additional Web Resources* for this chapter
  - Association for Manufacturing Excellence, *www.ame.org*
  - APICS—The Educational Society for Resource Management, *www.apics.org*

Additional Resources Available Only in WileyPLUS

- Use the *e-Book* and launch directly to all interactive resources
- Take the interactive *Quick Test* to check your understanding of the chapter material and get immediate feedback on your responses
- Check your understanding of the key vocabulary in the chapter with *Interactive Flash Cards*
- Use the *Animated Demo Problems* to review key problem types
- Practice for your tests with *additional problem sets*
- *And more!*

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