CHAPTER FIVE

FACILITY LAYOUT

Whenever an existing facility is renovated or a new facility designed, the chance exists to develop a layout that will improve process flow and minimize wasted space. When a new facility is designed, the facility layout should be integrated into the architectural design. Limitations on building lot size and shape, however, may heavily influence the layout configurations available. In other situations, a new layout is achieved simply by renovating an existing area, in which case the size and shape of the area are set, and the limitations relate to the funds available.

Planning facility layout is important for many reasons. The amount of capital invested in new construction or renovation is usually substantial. The results are long-term: while minor modifications may be possible, the overall layout will last well into the future. Furthermore, layout has an enormous effect on daily operations. Not only does layout dictate the distance a patient must travel from one department to another; it also influences which staff members are likely to interact and communicate.

The basic goals in developing a facility layout should be functionality and cost savings. Functionality includes placing the necessary departments, such as the operating and recovery rooms, close together. Functionality also includes keeping apart those departments which should not be together. Overall, functionality includes aspects of a layout which may not be immediately quantifiable, such as facilitating communication and improving staff morale.

Cost savings include reduction in travel times between areas, reduced construction costs by minimizing the space required, and allowing for reduced staffing by placing similar job functions close together. Two key elements of these goals are saving space and reducing the travel distance and time between departments. The amount of space allocated to a given department often is set by factors beyond the control of the facility planner, whose job it then is to make the most of that space. A poorly designed workspace harms both productivity and quality. Another aspect, the travel distance between departments, is a cost that can reach enormous proportions long-term. What may seem a short walk to a designer may add up, over the life of a facility, to days lost to travel. That not only adds to costs, but also weakens staff morale.

Facility layout is a complex process with many variables. Given unlimited time, space, and funding, it would be possible to develop and create the optimal layout. Given the constraints on any project, though, layout planning should still provide the best layout possible in any situation—one that can save money, improve the quality of care, and/or improve staff morale. A good layout will draw on the experiences of the planner, the technical knowledge of the staff who will be using the facility, a strong understanding of how to minimize wasted space and movement, and the forecasts of future needs. Although a planner usually acquires most of these skills, certain technical knowledge of a field is something the facility layout planner may never acquire. A strong understanding of the tools to minimize wasted space and movement, however, is readily taught and provides a good background from which to begin a facility layout (Stevenson, 2002; p. 232).

The three basic types of layouts are the product layout, the process layout, and the fixed-position layout. These layouts may be applied to either a single department or an entire facility (group of departments). Therefore the elements of the layout may be either whole departments or individual pieces of equipment (hospital beds, cafeteria equipment). An actual facility layout is almost always a mixture of the three basic types. A hospital may have an overall process layout as all the departments are grouped (intensive care, nursing units, administration). At the department level, there may be some product layouts (cafeteria, labs), and fixed-position layouts (an operating room).

Product Layout

The product layout arranges equipment (departments) in the order of product process flow. This type of layout is generally used in a production setting, where services (processes) are standardized and there is little variation, such as an assembly line. A product layout is generally less flexible and requires higher initial

equipment cost, but minimizes process cycle time and increases equipment utilization. The product layout might be used for a hospital cafeteria.

The specifics of a product layout are generally determined by the product or service itself. Most of the decisions involve balancing the line so that each station has approximately the same cycle time, the time for one item to pass through that workstation. If one workstation takes much longer than the next, then the second workstation is likely to spend much time waiting for parts from the first. Conversely, if the second workstation takes longer than the first, then the first is likely to spend much time waiting to move parts to the second (Stevenson, 2002; pp. 232–235). Since variability is inherent in patient care, the product layout is rarely useful in health care other than for supporting activities. Although the processes involved in patient care may be common among a group of patients with a similar diagnosis, the amounts of time that patients spend in each process must of necessity vary greatly. A cafeteria line is a common example of a health service industry product layout.

Process Layout

The process layout groups types of processes (departments, equipment, and so on) together to provide the most flexibility. Examples of a process layout can be found in physician offices (group practice), clinics, or hospitals. The hospital groups together functions such as intensive care, surgery, emergency medicine, and radiology as separate departments. This arrangement allows one patient entering through the emergency room to be seen in radiology, possibly surgery, and then intensive care, and another to be admitted directly for elective surgery and then to intensive care. The variability among patients makes such flexibility necessary. Another complicating factor is that it is often not clear when a specific bed will become open, so that scheduling a particular patient for a particular bed may not be possible. The downside of a process layout is high material handling costs. While it is necessary to have the flexibility to move patients from one department to any other department, it saves time to move the patient through adjacent departments along a common path.

Process Layout Tools

The many tools for designing a process layout generally weigh both quantitative and qualitative factors in deciding which departments should be placed closer together. The number of trips that employees make between two departments is a quantitative measure that can approximate the cost of having the two departments

far apart. Hazards such as supplemental oxygen and open flames (as in a kitchen) are qualitative factors to consider.

Qualitative factors are easily analyzed in a closeness rating chart, developed by Richard Muther (1962), named systematic layout planning (SLP). The closeness rating chart is essentially a grid that qualitatively assesses the desired closeness between departments. For some departments, closeness may be undesirable. The grid of a closeness rating chart resembles the mileage chart on a map; the rating for department A relative to B is the same as the rating for B relative to A. Codes denote the desired closeness, according to the relative strength of the closeness: A—absolutely necessary, E—very important, I—important, O—ordinary importance, U—unimportant, and X—undesirable. The codes take these factors into consideration: a) whether similar equipment or facilities are used, or similar work performed; b) sharing the same personnel, records, and communication; c) sequence of workflow; and d) unsafe or unpleasant conditions (Muther and Wheeler, 1962). Different colors for the codes may make the chart more visually effective, but are not necessary to the tool. The closeness rating chart may be used to create a block diagram for an effective layout. The chart may also be used to check the effectiveness of a layout that was created using another method or computer tool.

Using a heuristic rule, the first step in assigning departments to available spaces according to desired closeness relationships is to identify the absolutely necessary and the undesirable relationships. That is, all departments with A and X coded relationships would be identified and their workplaces laid out on the available space. Then other departments with E, I, and O ratings would fit in. Let us develop a layout to illustrate this method.

Example 5.1

A long-term care facility will be constructed with total available area of 200×400 ft., as shown in Figure 5.1. The dimensions of each department and the desired relationships among the departments are depicted in Figure 5.2. A functional layout with the given parameters is desired.

As can be observed from Figure 5.2, it is important that the patient room area and the ambulance entrance be close to each other. On the other hand, the main entrance is not desired to be close to the laundry facilities or to the ambulance entry. The next parameter is the size of each department (also shown in Figure 5.2), so an algorithm can be applied to provide solution to the layout, using the closeness rating method. It should be noted that the patient room area will be the space left after other departments are logically laid out according to the closeness ratings algorithm.

Following the heuristic algorithm suggested above, the following A and X relationships are identified: namely, in A relationships, the nurses' station and the

FIGURE 5.1. AVAILABLE SPACE FOR LAYOUT OF LONG-TERM CARE FACILITY.

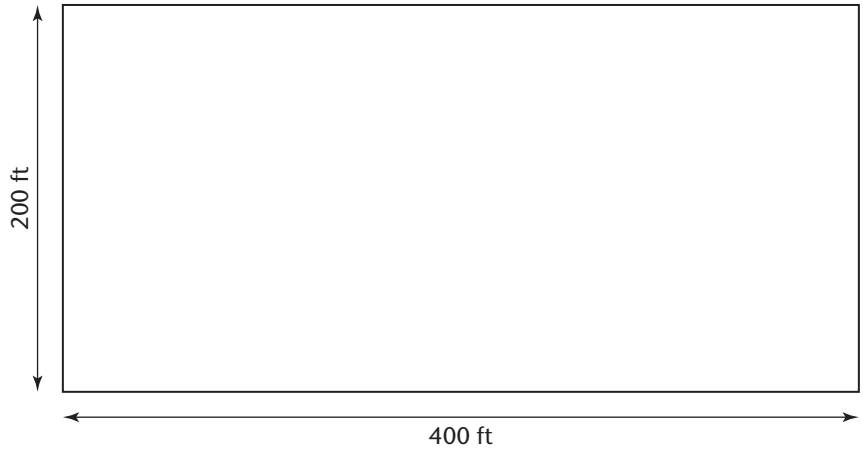

FIGURE 5.2. CLOSENESS RATING CHART FOR LONG-TERM CARE FACILITY.

Area in Feet	Department
40 * 80	1. Nurses' Station
40 * 40	2. Ambulance Entrance
Remaining Space	3. Patient Room Area
40 * 80	4. Laundry
80 * 80	5. Main Entrance
40 * 80	6. Dietary Department

A					
E	O				
U	I				
I	X	E			
E	U				
X	I				
U					
X					

A = Absolutely Necessary
E = Very Important
I = Important
O = Ordinary Importance
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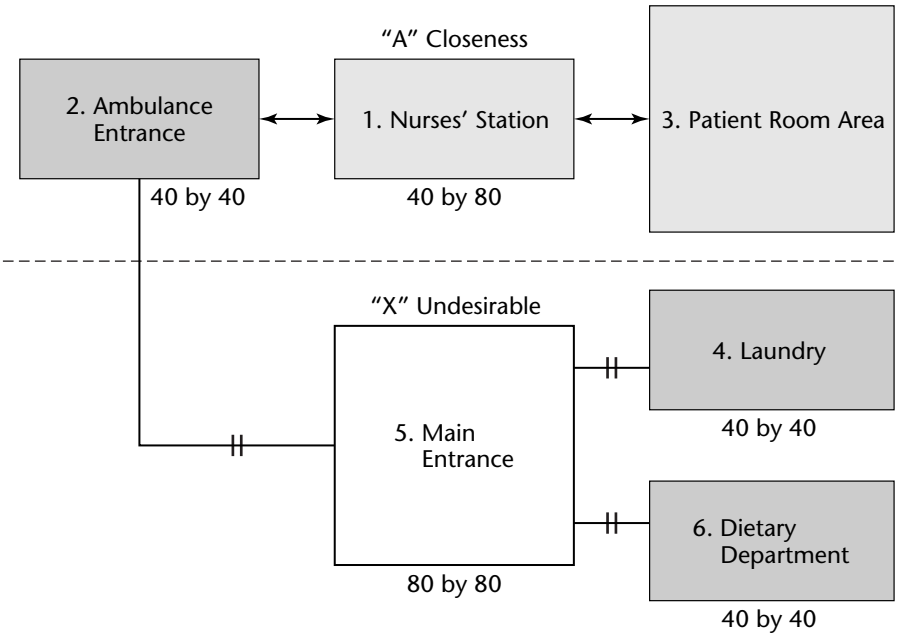
X = Undesirable

FIGURE 5.3. A AND X CLOSENESS REPRESENTATION.



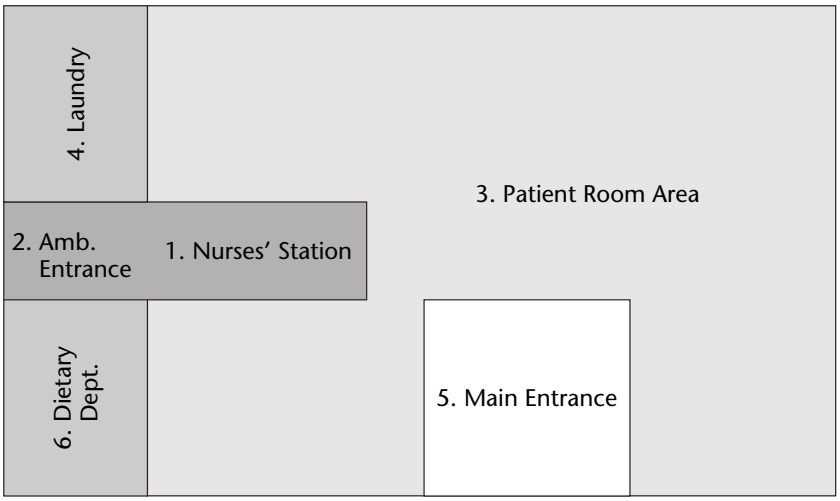
ambulance center, as well as the nurses' station and patient areas, must be adjacent. On the other hand, in X relationships, the main entrance must be away from the ambulance entrance, laundry, and dietary department.

A	X
1–2	2–5
1–3	4–5
	5–6

The next step is to identify the most frequent department in each relationship. In A relationships, the nurses' station (1) appears twice, and in X relationships the main entrance (5) appears three times. Using these departments as a starting base, we can show a draft of the desirability on a layout drawn to scale, as underlined by the A and X relationships. Figure 5.3 displays this start.

We should note that the patient room area and the ambulance entrance have E ratings, so they can be close each other. Similarly, the dietary department can be close to the nurses' station. Although there is no unique solution to this problem, a layout solution can be conceived as shown in Figure 5.4.

FIGURE 5.4. LAYOUT SOLUTION.



Method of Minimizing Distances and Costs

If the objective of the layout is to create efficiencies in functional areas where repetitive processes (nurses walking in hallways to fetch supplies or delivering care for patients) occur, then minimizing the costs or repetitive distances traveled becomes a goal. Data representing such traffic can be summarized in a from-to chart. A from-to chart is generally a table listing the departments to be considered and the number of trips (or flow) between them in a given period. Once such traffic information is identified, those areas with the most frequent interaction may be assigned adjacent to each other, and an initial layout can be generated. However, there may be many possible assignments. If three departments are to be assigned three spaces, there are six possible layouts. This is calculated by factorial formulation, $n!$, where n represents departments. Increasing the number of departments dramatically increases the number of possible solutions. For example, for four departments, 4!, there are 24 possible assignments.

More formally, D_{ij}, W_{ij}, and C_{ij} represent the distance, interdepartmental traffic, and cost, respectively, between departments i and j. The objective of the layout is to minimize total cost (TC) function, and the problem can be specified as:

$$\text{Minimize TC} = \sum_{ij} D_{ij} * W_{ij} * C_{ij} \qquad [5.1]$$

As with any quantitative tool, however, the layout developed is only as good as the quantitative data used. Care should be taken to make sure that current

data are used, though without incurring data acquisition costs greater than the savings to be generated by the design effort. The time period chosen should be long enough to account for fluctuations over time, so that the data represent long-term travel between the departments. This method rarely, if ever, develops an optimal layout, so that may be implemented as the lowest cost that can be obtained by trying different assignments of the departments to the available spaces according to the frequency of interactions (flow), W_{ij}. Almost always, the initial layout will require modification to accommodate qualitative factors that do not show up using the from-to chart. Exhibit 5.1 illustrates a

EXHIBIT 5.1. FROM-TO CHART FOR A SMALL HOSPITAL.

A = operating room
B = emergency room
C = outpatient clinic
D = intensive care unit
E = nursing units
F = dietary dept

From \ To	A	B	C	D	E	F
A	-	10	3	42	12	1
B	23	-	0	31	15	2
C	11	1	-	3	5	0
D	38	7	0	-	39	21
E	19	6	4	27	-	36
F	0	3	0	23	35	-

Note that this chart may be condensed to:

	A	B	C	D	E	F
A	-	33	14	80	31	1
B	-	-	1	38	21	5
C	-	-	-	3	9	0
D	-	-	-	-	66	44
E	-	-	-	-	-	71
F	-	-	-	-	-	-

from-to chart for a small hospital, displaying daily interactions, W_{ij}, among six departments.

As noted earlier, for this particular problem there may be 6!, or 720 possible solutions. If we obtain the distances between departments and assume equal costs (C_{ij}) of flow (for example, nurses' travel times can be converted to cost by using wage information), which layout solution provides the minimal total cost? Let us illustrate this with a simple example.

EXAMPLE 5.2

Consider the departments A, B, and C of a small hospital. Assume the distance between the locations 1 and 2 to be 100 feet, between 1 and 3 to be 200 feet, and between 2 and 3 to be 100 feet. Assign these departments to locations 1, 2, and 3 in a rectangular space.

Assuming that on average a nurse can walk 100 feet in 30 seconds and earns $48.00 per hour including fringe benefits, what is the total initial cost of the initial layout? A summary of the information for this problem is shown in Table 5.1. Since there are three departments to be assigned three locations, there are 3! = 6 possible assignment configurations, as shown in Table 5.2.

TABLE 5.1. DISTANCE AND FLOWS AMONG THREE HOSPITAL DEPARTMENTS.

Distance Among Locations				Flow Among Departments			
	Location				Department		
From/To	1	2	3	From/To	A	B	C
1	—	100	200	A	—	10	3
2	100	—	100	B	23	—	1
3	200	100	—	C	11	1	—

TABLE 5.2. POSSIBLE ASSIGNMENT CONFIGURATIONS OF DEPARTMENTS TO THREE LOCATIONS.

Assignment Configurations	Locations		
	1	2	3
1	A	B	C
2	A	C	B
3	B	A	C
4	B	C	A
5	C	A	B
6	C	B	A

TABLE 5.3. RANKING DEPARTMENTS ACCORDING TO HIGHEST FLOW.

Trips Between Locations	Distance in Feet	Department Pair	Workflow	Total Flow
1–2	100	B–A	23	33
2–1	100	A–B	10	
2–3	100	C–A	11	14
3–2	100	A–C	3	
1–3	200	C–B	1	2
3–1	200	B–C	1	

To make a proper assignment, locations can be organized in pairs based on the minimum distance and the highest departmental flows. Then the highest total departmental flow for department pairs can be calculated as shown in Table 5.3. The department pair A-B/B-A has the highest total flow, at 33 interactions. Hence, it is convenient and logical to place departments A and B to locations 1 and 2, and department C to location 3. So we would choose to implement assignment configuration #1 from Table 5.2.

The next step would be calculation of the total cost (TC) for this configuration. If a nurse can walk 100 feet in 30 seconds, the cost of that walk is 40 cents (in one hour there are 3,600 seconds, hence 3,600/30 = 120 possible such walks; \$48/120 = \$0.40 per 100-foot walk).

Table 5.4 summarizes the TC for this configuration. We used a heuristic approach to find this solution. Other configurations (for example, 2 through 6) can be calculated, and then the minimum TC among the configurations would be the best solution.

TABLE 5.4. TOTAL COST OF A LAYOUT.

Department	To	Flows	Location	Distance	Distance * Flow $D_{ij} * W_{ij}$	Combined $D_{ij} * W_{ij}$	Total Cost $D_{ij} * W_{ij} * C_{ij}$
A	B	10	1–2	100	10 * 100 = 1,000	1,600	1600 * .4 = \$640
	C	3	1–3	200	3 * 200 = 600		
B	A	23	2–1	100	23 * 100 = 2,300	2,400	2400 * .4 = \$960
	C	1	2–3	100	1 * 100 = 100		
C	A	11	3–1	200	11 * 200 = 2,200	2,300	2300 * .4 = \$920
	B	1	3–2	100	1 * 100 = 100		
Total						6,300	\$9,520

As can be seen, calculating each configuration is computation-intensive, and enormously so when the number of departments increases. For that reason, computer-based solutions for the minimum total cost are desirable.

Computer-Based Layout Programs

Several computer programs can generate the initial possible layouts, using both the from-to chart method and the closeness rating chart. Some of these programs also allow the user to consider travel costs associated with movement between different departments. Most of the programs start with departments in random positions, calculate some relative cost measure, and then move departments in pairs or triplets until the layout with a lower relative cost is found. It is important to note that depending on which method is used, some programs may not necessarily generate an optimal solution. Although computer programs generate only an initial layout from which to start, that is an excellent starting point that may lead to a layout that might not otherwise have been developed.

The most widely used program in this area is Computerized Relative Allocation of Facilities Technique (CRAFT) (Muther and Wheeler, 1962). WinQSB provides a CRAFT-based layout where distance, flow, and costs are part of the required inputs. The two most commonly used distance measures between departments can be straight line, also called Euclidian distance or squared Euclidian; and rectilinear distance, known as Manhattan distance, which emulates the streets of Manhattan in New York City. Manhattan distance means that, to go from one place to another, one has to travel up or down, right or left through the streets, rather than crossing to the buildings. Most real-life problems have similar conditions: in order to go from one department to another, one has to walk through corridors, take elevators, and so on, emulating travel in Manhattan. Hence, the rectilinear distance measure will be used in our computerized layout solutions.

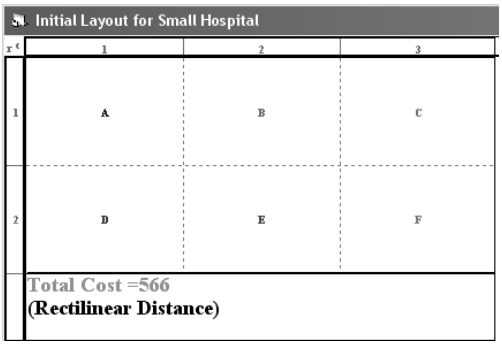
The solution to the example of the small hospital problem presented in Exhibit 5.1 is generated using WinQSB. For simplicity, we assume that the space available is rectangular and that all departments are equal in size. The available space can hold two departments widthwise, and three departments lengthwise. Figure 5.5 shows the data entry and initial layout for the problem. Total cost (TC) is shown at the bottom of the layout as 566. After two iterations, a final layout is generated with a total cost of 553. Hence, from the initial layout to the final layout, as shown in Figure 5.6, a savings of 13 units of cost appears. If this is converted to dollars per year, one can add up the savings to compare against the costs of the layout (being changed from the existing one).

FIGURE 5.5. WINQSB SOLUTION TO A SMALL HOSPITAL LAYOUT PROBLEM.

Functional Layout Information for Small Hospital

1 : Location Fixed | No

Department Number	Department Name	Location Fixed	To Dep. 1 Flow/Unit Cost	To Dep. 2 Flow/Unit Cost	To Dep. 3 Flow/Unit Cost	To Dep. 4 Flow/Unit Cost	To Dep. 5 Flow/Unit Cost	To Dep. 6 Flow/Unit	Initial Layout in Cell Locations [e.g.,
1	A	No		10	3	42	12	1	(1,1),(2,2)
2	B	No	23		0	31	15	2	(1,2),(2,3)
3	C	No	11	1		3	5	0	(1,3),(2,4)
4	D	No	38	7	0		39	21	(2,1),(3,2)
5	E	No	19	6	4	27		36	(2,2),(3,3)
6	F	No	0	3	0	23	35		(2,3),(3,4)

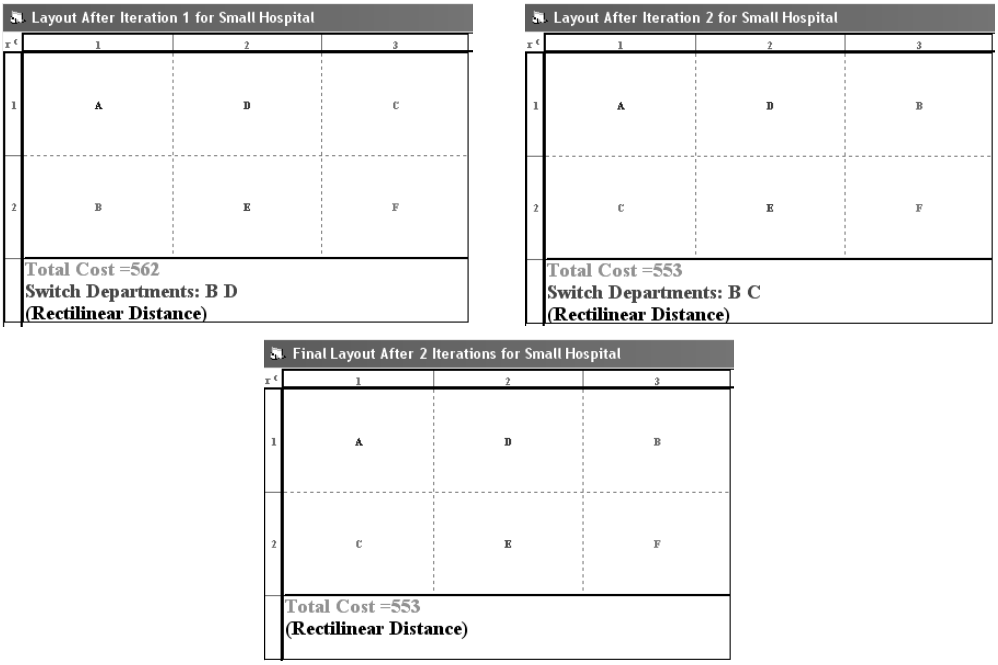


Source: Screen shots reprinted by permission from Microsoft Corporation and Yih-Long Chang (author of WinQSB).

Fixed-Position Layout

The fixed-position layout consists of the fixed service positions where personnel and materials come together to perform the service. In industry, this type of layout is generally used when the product being processed is either too bulky or too delicate to move (such as airplane assembly or spacecraft assembly). In health care, consider that in an operating room the service position is the operating table. In an inpatient hospital room (especially in an intensive care unit) the service position is the patient bed. Generally, designing a fixed-position layout entails positioning several service positions within a given area, each of which may require an adjacent but separate support area (such as a scrub room with an operating room). Developing a fixed-position layout may not be as simple as it seems. Often, conflicts about space constraints and even timing have to be resolved. For example, in an operating room a suspended x-ray machine and overhead lighting may have to be used in the same space.

FIGURE 5.6. WINQSB ITERATIONS AND FINAL LAYOUT FOR A SMALL HOSPITAL.



Source: Screen shots reprinted by permission from Microsoft Corporation and Yih-Long Chang (author of WinQSB).

Summary

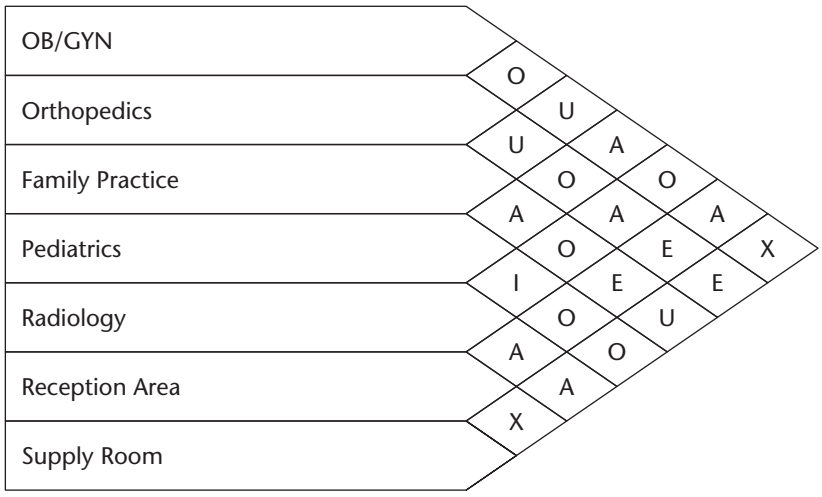
This chapter explored concepts and methods for layout decisions. Improving the layout of a health care facility is one of the methods referred by reengineering and productivity that are discussed in Chapters Six and Nine. Health care managers should keep in mind that improved layouts that save costs would pay the one-time layout-change costs over the years. A cost-benefit analysis showing such cost recovery is an essential part of justifying such changes as well as making the facility more efficient.

Exercises

Exercise 5.1

Figure EX 5.1 shows the relationship diagram among the seven sections of a PPO office. The dimensions of the OB/GYN, orthopedics, family practice, pediatrics, and radiology departments each are 200 × 200 feet; the reception area and supply room each are 200 × 400 feet. Arrange these seven departments in a space given as 600 × 600 feet, so that the layout meets the conditions specified in the relationship diagram matrix.

FIGURE EX 5.1

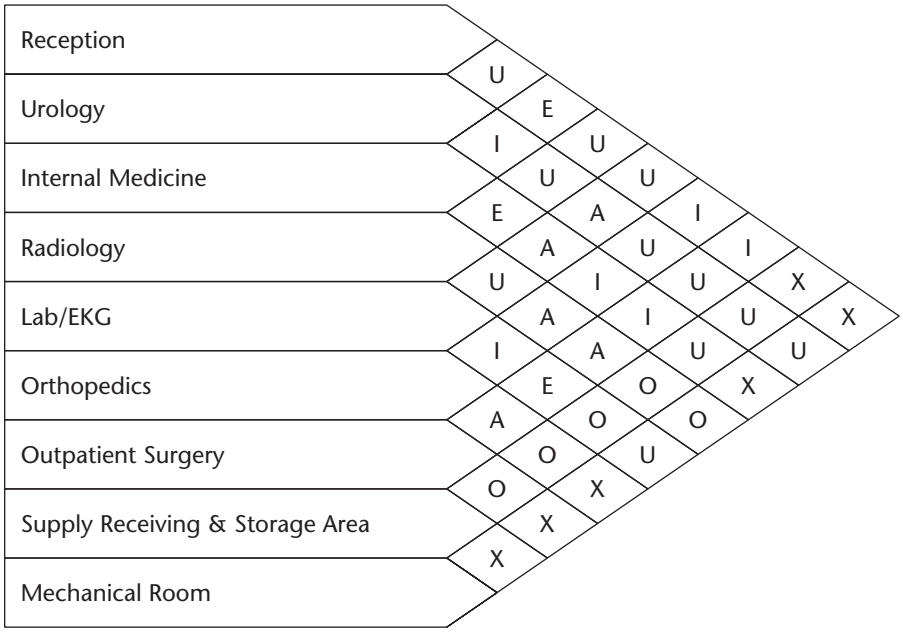


A = Absolutely Necessary
E = Very Important
I = Important
O = Ordinarily Important
U = Unimportant
X = Undesirable

Exercise 5.2

A relationship diagram among nine equal-size sections of a small clinic was developed by the building committee of the organization, as shown in Figure EX 5.2.

FIGURE EX 5.2



A = Absolutely Necessary
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I = Important
O = Ordinarily Important
U = Unimportant
X = Undesirable

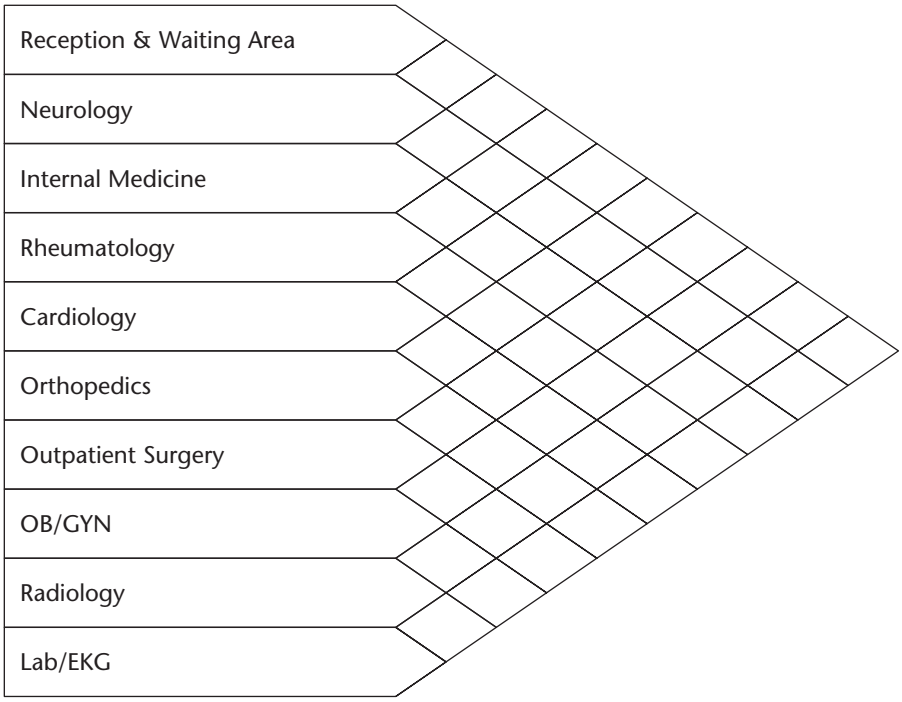
Arrange the clinic's sections so they satisfy the rating conditions. The final layout should be arranged as 3 by 3 equal-size sections where the mechanical room is at the lower right corner of the building, as shown below:

		Mechanical room

Exercise 5.3

Develop a relationship rating for the nine departments of a new clinic, plus its reception area. The storage and mechanical area has no role in clinical operations, and its location is predetermined.

FIGURE EX 5.3



Place the clinical departments in the following layout according to the conditions developed in Figure EX 5.3.

	Reception and Waiting Area		
			Storage & Mechanical

Exercise 5.4

Table EX 5.4 shows the current and proposed layouts for a group practice. The cost of travel per 1,000 feet is estimated to be $4. Moving departments costs $50,000 each.

TABLE EX 5.4

Current Layout			
Waiting room	Exam room area	Procedure room	Lab/EKG

Total transportation cost (flow * distance) = 3,225,000.

Proposed Layout			
Procedure room	Exam room area	Waiting room area	Lab/EKG

Total transportation cost (flow × distance) = 2,381,100.

a. What are the efficiency savings of the proposed layout?
b. What is the cost of the proposed layout?
c. In how many years can the cost of the new layout be recovered?

Exercise 5.5

Determine which placement of departments for a newly designed urgent care center will minimize transportation costs. Assume that it costs $1 to travel a meter. Flow and distance matrices are shown in Table EX 5.5.

TABLE EX 5.5

Distances (in meters) From/To	**Women's Center**	**Behavioral Health**	**Cardiac Care**	**Day Surgery**	**Lab/EKG**	**Radiology**
Women's Center	—	60	120	150	180	210
Behavioral Health		—	60	90	120	180
Cardiac Care			—	30	60	100
Day Surgery				—	30	60
Lab/EKG					—	60
Radiology						—
Trips (per month) From/To	**Women's Center**	**Behavioral Health**	**Cardiac Care**	**Day Surgery**	**Lab/EKG**	**Radiology**
Women's Center	—	0	0	2,400	600	1,200
Behavioral Health	10	—	2,650	90	650	800
Cardiac Care	1,260	5	—	30	60	100
Day Surgery	920	0	1,550	—	30	60
Lab/EKG	1,900	300	3,000	930	—	60
Radiology	320	10	1,750	575	60	—

Exercise 5.6

The administrator of the Vacationers Hospital (VH) recognized the amount of traffic in the corridors. This prompted her to think about possible problems with the current layout. The core work of the patient care is performed in an area 300 × 150 feet, as shown in Table EX 5.6.1.

TABLE EX 5.6.1.

Entrance/initial processing	Waiting room	Exam room I
Exam room 2	X-Ray	Lab/EKG
Operating room	Recovery room	Cast setting room

150 feet

300 feet

All rooms (departments) measure 100 feet (length) by 50 feet (width). Walking distance from one department to another is completed by rectangular working patterns. Assuming that a trip originates from the center of a department and terminates at the center of an adjacent department, a person would walk 150 feet (25 feet from the center of the originating department to the hallway, 100 feet on the hallway to an adjacent department, and 25 feet from the hallway to the center of the adjacent department). The results of a six-month-long work sampling study analyzing the movement of VH patients and staff between the departments, averaged per month, are presented in a from-to chart:, as shown in Table EX 5.6.2.

TABLE EX 5.6.2. FROM-TO CHART: MONTHLY TRAFFIC BETWEEN DEPARTMENTS (NUMBER OF PEOPLE IN MOTION).

Department		1	2	3	4	5	6	7	8	9
1	Entrance/Initial processing	.	.	.	.	.	.	.	.	.
2	Waiting room	1,900		.	.	.	.	.	.	.
3	Exam room 1	1,750	250	.	.	.	.	.	.	.
4	Exam room 2	1,600	300	900	.	.	.	.	.	.
5	X-Ray	500	675	750	1,005	.	.	.	.	.
6	Lab/EKG	800	650	880	870	400		.	.	.
7	Operating room	375	0	225	300	325	650	.	.	.
8	Recovery room	0	0	0	0	0	0	1,125	.	.
9	Cast-setting room	0	0	0	0	985	525	0	0	.

A consultant informed the administrator that every 1,000 extra feet walked (by either patients or staff) cost $5.50 a month in terms of lost productivity (assuming flows and costs are symmetrical among departments). The objective is to minimize

unnecessary walking by changing the location of each department on the basis of traffic data. To move a department costs $20,000 per room, except for lab/EKG, operating room, and x-ray, which cost $75,000 each.

a. Determine whether it would be worthwhile to change the layout of the hospital.
b. How many years would it take to recover the cost of layout changes?

(Hint: Total transportation costs of this problem can be calculated using WinQSB Software).