CHAPTER FOUR

FACILITY LOCATION

Locating health services in a community is not an everyday decision for health care managers. However, it is important to study this problem, not so much simply because of its strategic nature, but because, in addition, today's health care facilities are operating in competitive markets, which means that building or relocating new facilities is a strategic decision that cannot tolerate mistakes. A health care facility must not be built where demand is mediocre, or will be so. Similarly, the facility must be sized to meet both current and future demand accurately, or the location must have expansion opportunities.

Many complex factors, including an area's population, currently available services, and present and future demand must be considered in locating health care facilities. For example, R. Timothy Stack, President and CEO of Piedmont Medical Center in Atlanta, Georgia, has stated that Atlanta has a population of 4.2 million living in twenty counties around the city center. Many of these counties are expected to grow by as much as 20 percent over the next five years. By 2025, demand for hospital beds in greater Atlanta is projected to increase by 60 percent, one of the fastest growth rates in the United States.

Equally important to consider, the Atlanta health care market is fragmented. There is no predominant referral hospital, and no clear market leaders overall in offering various specialized services. Currently greater Atlanta has sixty-one hospitals, including a Veterans Affairs Hospital. Furthermore, the city is headquarters of both the federal Centers for Disease Control and the American Cancer Society. In such a growing but complex health care market, the larger facilities are planning to build new hospitals and/or expand existing ones, as well as adding tertiary programs. (R. T. Stack, 2004).

In health care, facility construction faces the hurdle of first obtaining a certificate of need (CON). Deciding on a location does not guarantee a quick startup, as in retail or fast-food industries. In the health care industry, then, sound forecasting of current and potential demand is indispensable for location decisions. Usually that means examining the primary, secondary, and tertiary markets for the proposed facility, especially for hospitals, whose managers must examine such population characteristics as age, sex, education, employment, and prevailing epidemiological outcomes (Virginia Atlas of Community Health, 2004). The many factors in demand analysis delineate the kind of facility that should be built or relocated to the location(s) under consideration. Examples are the service mix (young population needing OB/GYN and pediatric specialties), technology (extensive cardiac technologies for aged populations), and size.

A market shift of population to other localities (for example, the suburbs) is a major reason for location decisions. As part of marketing strategy, health care facilities want to expand their services to new suburbs by opening satellite locations. Multiple-campus health care facilities are now almost the norm in many markets for hospital chains, IDS, or strategic health care alliances. They also serve to feed complicated cases to the main hospital.

If demand for the current health care facility is strong and growing, and there is enough land and capability to expand it, the facility need not move to a new location unless other factors (such as high operational costs, traffic congestion, and parking facilities) have become significant. On the other hand, a new location decision does become necessary when a facility cannot be expanded because no more land is available to it. If the demand is strong in the current location, facility managers would seek new, additional sites, to distribute the supply of health care for the strong demand by opening satellite facilities. However, if the demand has shifted to the suburbs and the current facility is very old, a more appropriate decision would be to build a new facility at a new location.

In all cases, location decisions are *strategic,* requiring a long-run commitment of the health care organization's resources. To identify acceptable alternatives, both for the physical location and for the method of expansion, using appropriate decision tools as well as analytical skill is necessary.

A location decision for health care managers is generally arrived at through this process: 1) an agreement on the decision criteria for evaluations of alternatives (profit, market share, and community considerations); 2) identification of important factors; 3) development of location alternatives; 4) evaluation of the alternatives; and 5) final selection. Decision criteria should include factors related to the region, the community, and the site that encompass both cost and nonfinancial concerns.

Regional factors include availability of markets or market stakeholders (patients, physicians, payers, and employers). Community factors include the attitudes of citizens to new developments, the availability of and proximity to supporting services (for example, medical staff offices, social services, security, and allied health services), and environmental regulations specific to that community. Site-related factors include land, size and usable area, acquisition costs; existing facilities on the land if they indicate any renovation or demolition costs; access to public and other transportation, roads, parking; zoning, and CON (Stevenson, 2002; pp. 358–366).

Location Methods

Various quantitative methods are available to aid location decisions, depending upon the nature of the problem. In this chapter we present cost-profit-volume analysis, factor rating methods, multi-attribute methods, and the center-of-gravity method; one or more can be used to make an informed decision. No one method may be right for all facility location problems; however, cost analysis is always part of the solution package.

Cost-Profit-Volume (CPV) Analysis

In this method, also known as break-even analysis, health care managers evaluate the fixed costs and the variable costs of building and operating a facility in each of the alternative locations. Of course, the revenues and resulting profits expected to be generated by volume (demand) help to justify the selection of a site. In general, the cost structures of each site, especially the fixed cost, will differ from each other, as will volume. Besides hospitals, examples of facilities that can face location decisions and hence use CPV analysis would be nursing homes, assisted living facilities, independent laboratories, imaging centers (MRI, CAT scan), physician practice (group) offices, and small to medium-size clinics. The CVP analysis assumes one product line at a time for simplicity. For multiple product lines such as hospitals, CVP analysis may be based on Diagnosis Related Groups (DRGs) or on each product; then the analysis can be aggregated to the hospital level. For simplicity, we will examine the use of this method for an imaging facility.

In CVP analysis, the following relationships define the costs and profits:

$$\begin{aligned} \text{Profit} &= \text{Revenue } (R) - \text{Total cost } (TC), \text{ where} \\ \text{Revenue} &= \text{Unit Price } (p) * \text{quantity } (Q), \\ \text{Total cost} &= \text{Fixed cost } (FC) + \text{variable cost } (VC), \\ \text{Variable cost} &= \text{variable cost per unit } (v) * \text{quantity } (Q). \end{aligned}$$

More formally,

$$\text{Profit} = R - TC \qquad [4.1]$$

$$R = p * Q \qquad [4.2]$$

$$TC = FC + VC \quad \text{and} \qquad [4.3]$$

$$VC = v * Q \qquad [4.4]$$

or

$$\text{Profit} = (p * Q) - [FC + v * Q] \quad \text{and} \qquad [4.5]$$

$$\text{Profit} = (p - v) * Q - FC. \qquad [4.6]$$

Analysis may first consider the total cost outcomes, then one performs profitability analysis using possible charges (price) per unit. The above formula can be used to determine the volume for an assumed level of profit:

$$Q = \frac{\text{Profit} + FC}{p - v}. \qquad [4.7]$$

EXAMPLE 4.1

Imaging using electron beam computed tomography (EBCT) is a technology for diagnosing and evaluating the presence of coronary artery heart disease and diseases of the lung. Keep-Me-Healthy Imaging Company (KMHIC) provides services in fifteen locations across the country and is interested in expanding their centers to other locations. KMHIC expects to collect $300 per unit of service from patients' insurance. The cost information is determined for the next East Coast location with three alternative sites as follows:

Site	Fixed Cost/Year (in million $)	Variable Cost Per Unit	Expected Demand/Year
Baltimore	1.6	$30	15,000
Norfolk	1.5	$40	10,000
Richmond	1.25	$80	8,000

What would be the ideal location based on CPV analysis?

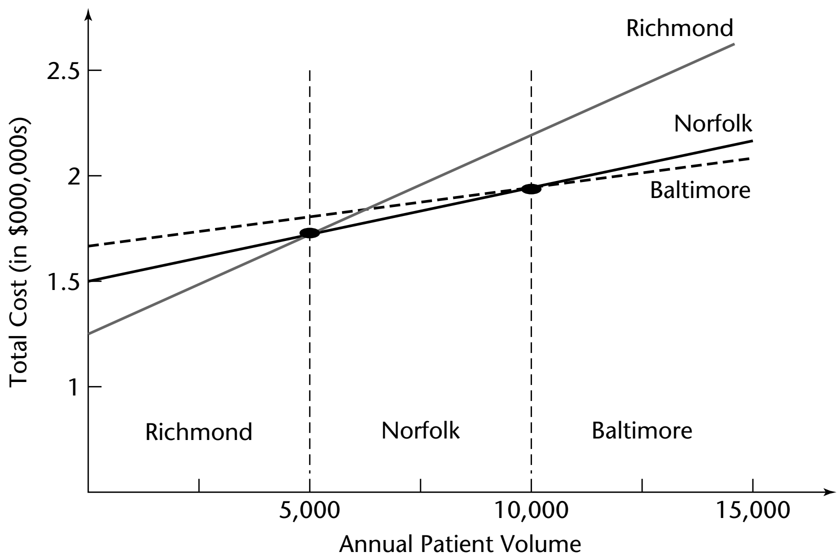
Solution: Calculation of total cost for each of the three sites using formula [4.3] yields the lowest cost for the Richmond site.

Site	*TC* = *FC* + *v* * *Q*
Baltimore, MD	1,600,000 + 30 * 15,000 = $2,050,000
Norfolk, VA	1,500,000 + 40 * 10,000 = $1,900,000
Richmond, VA	1,250,000 + 80 * 8,000 = $1,890,000

■

A sensitivity analysis for involved parameters will further aid decision making. One of the parameters in this case is volume (quantity). Hence, a graphical solution to this problem can provide a comfort zone for the health care manager, based on expected volumes, in deciding which site is more plausible. Figure 4.1 depicts the best sites on the basis of patient volume. If annual volume is fewer than 5,000 patients, from the total cost perspective Richmond is the best site. If the annual expected volume is between 5,000 and 10,000 patients, the lowest costs would occur at the Norfolk site. Baltimore is the best location for patient volumes higher than 10,000 per year. Figure 4.1 traces the lowest total cost curves for each of the volume zones.

FIGURE 4.1. TOTAL COST OF ALTERNATIVE IMAGING SITES.

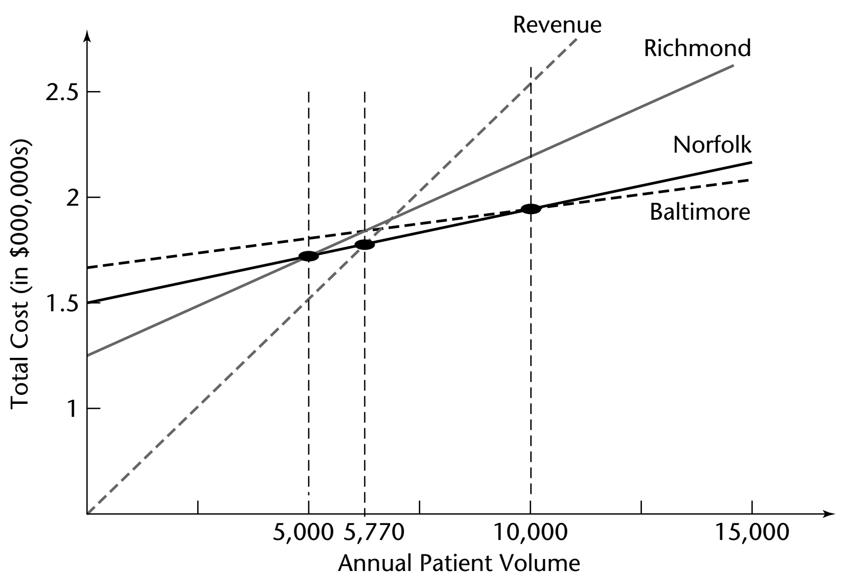


When profit is the immediate consideration, using formula [4.6], Profit = $(p - v) * Q - FC$, for the same sites, we obtain:

Site	Profit = $(p - v) * Q - FC$
Baltimore, MD	[(300 − 30) * 15,000] − 1,600,000 = $2,450,000
Norfolk, VA	[(300 − 40) * 10,000] − 1,500,000 = $1,100,000
Richmond, VA	[(300 − 80) * 8,000] − 1,250,000 = $510,000

The Baltimore site is almost five times as profitable as the Richmond one. Clearly, two different choices emerge based respectively on total cost and on profit. Although the decision may seem very clear to open the site in Baltimore, if the expected volumes are not realized as forecast, the profit-based decision may not prove to be the best one. To illustrate this graphically, Figure 4.2 imposes the revenue line to the existing total cost for each site. Clearly, no site makes a profit before reaching annual patient volume of 5,770. From this point to 10,000 patients, Norfolk is the most profitable site (has the largest gap between the revenue and the cost line). With over 10,000 patients, Baltimore becomes the more profitable site.

FIGURE 4.2. PROFIT EVALUATION OF ALTERNATIVE SITES.



Factor Rating Methods

Factor rating methods are used when site alternatives have to be evaluated on attributes (factors) other than costs (money). Such attributes may be measured on a common scale (scoring from 1–100) or by multiple scales some of which are not numeric (acceptable, medium, good, and excellent). Thus, this method for evaluating alternative sites varies with information availability and scoring metric.

The first step in this methodology is to identify the relevant factors. The next step is to check whether all the factors can be evaluated by the same metric. Third, determine whether for this particular site decision any of the factors are more important than others; if so, either each factor can be ranked, or weights can be assigned to each factor according to its relative importance. Then an analysis of the scores (ranks and weights if applicable) is carried out to identify the best alternative. These analyses may be simple or weighted summations of assigned scores.

Example 4.2

A medical center would like to establish a satellite clinic to provide medical care for residents living in recently developed suburbs. Four potential sites are under consideration. Land acquisition, building, and equipment costs have been evaluated, as have population, education level, median household income, and percentage insured. As can be observed from Table 4.1, the factors are reported in different measurement units (metric), so they must be either converted to the same metric or analyzed using the multi-attribute procedures discussed in Chapter Three.

TABLE 4.1. FACTORS TO BE CONSIDERED IN ESTABLISHING A SATELLITE CLINIC.

	Zip Codes of Potential Sites			
Factors	**23059**	**23233**	**23112**	**23832**
Land	$350,000	$390,000	$245,000	$200,000
Building	$450,000	$450,000	$435,000	$425,000
Operating	$235,000	$240,000	$220,000	$205,000
Pop. Size	15,683	50,296	38,660	25,775
Elderly	7%	12%	6%	5%
Education	92%	96%	93%	90%
Income	$73,668	$67,917	$63,519	$61,738
Insured	88.2%	88.6%	88.5%	88.1%

Source for non-cost factors: Virginia Atlas of Community Health, 2004.

One way to convert the different scores to the same metric is to rate each site's value for a given factor, relative to the each of the others. For example, the most desirable value in land cost is \$200,000, at site 23832. In comparison, site 23059, with \$350,000, has a score of 57. The score is calculated using formula:

$$\text{Relative score} = \frac{\text{Most desirable outcome}}{\text{Evaluated outcome}} \qquad [4.8]$$

and

$$\text{Relative score} = \frac{\$200{,}000}{\$350{,}000} * 100 = 57.$$

In this example, lower costs; higher population size; higher percentages of those 65 and older, of high school graduates, and of these insured; and higher median income are considered desirable. If the most desirable outcome has the highest value (compared to the lowest, as in costs), the relative score is obtained by reversing the formula as:

$$\text{Relative score} = \frac{\text{Evaluated outcome}}{\text{Most desirable outcome}} \qquad [4.9]$$

For example, the median household income score for site 23233 is:

$$\text{Relative score} = \frac{\$67{,}917}{\$73{,}668} * 100 = 92.$$

A preliminary evaluation can be done by summing all the relative scores for each site. The site with the highest total score becomes the primary candidate for selection. In this case (shown in Table 4.2), site 23233, with a score of 723, is the best choice.

TABLE 4.2. RELATIVE SCORES ON FACTORS FOR A SATELLITE CLINIC.

	Zip Codes of Potential Sites			
Factors	**23059**	**23233**	**23112**	**23832**
Land	57	51	82	100
Building	94	94	98	100
Operating	87	85	93	100
Pop. Size	31	100	77	51
Elderly	58	100	50	42
Education	96	100	97	94
Income	100	92	86	84
Insured	100	100	100	99
Sum of relative scores	624	723	682	670

In this example, all factors, including costs and community, received the same treatment or equivalent weights. However, the relative values of the factors can differ for different decision makers who are choosing sites. For an example, cost factors might be considered more important than community factors. Similarly, the importance of the percentage of insured in the community might affect the survival of a clinic more than the percentage of high school graduates (implication of employability) would. In such cases, health care managers may want to assign relative weights to the individual factors. To do so, the least important factor is assigned a score of 1, and the other factors are compared relative to that factor. Let us suppose that the percentage of high school graduates is the least important factor and gets a score of 1. Compared to that factor, median household income is, say, fifteen times as important; the percentage sixty-five and older is five times as important; the percentage of insured is twenty-five times as important; population size is nine times as important; land acquisition and building costs are each twenty times as important; and operating costs are twenty-five times as important. The relative factor scores and weights are displayed in Table 4.3. To calculate their relative weights (importance), each score is divided by the total relative score, in this case 120. As shown in Table 4.3, for example, the percentage of insured has a weight of .208 (25/120), and land cost has a weight of .167 (20/120).

The next step would be to calculate a weighted aggregated score (a composite score) for each site. This is carried out by multiplying factor weights to site scores for each factor and then taking the sum. Table 4.4 illustrates these calculations.

Of the composite scores (weighted sums), site 23832 has the best score. This example demonstrates that weighted scores versus raw scores make a marked difference in site selection decisions.

TABLE 4.3. RELATIVE FACTOR SCORES AND WEIGHTS.

Factors	Relative Scores	Weights
Land	20	0.167
Building	20	0.167
Operating	25	0.208
Pop. Size	9	0.075
Elderly	5	0.042
Education	1	0.008
Income	15	0.125
Insured	25	0.208
Sum of relative scores	120	1.00

TABLE 4.4. COMPOSITE SCORES.

Factors	Weights	Zip Codes of Potential Sites			
		23059	23233	23112	23832
Land	0.167	57 * 0.167 = 9.5	51 * 0.167 = 8.5	82 * 0.167 = 13.6	100 * 0.167 = 16.7
Building	0.167	94 * 0.167 = 15.7	94 * 0.167 = 15.7	98 * 0.167 = 16.3	100 * 0.167 = 16.7
Operating	0.208	87 * 0.208 = 18.2	85 * 0.208 = 17.8	93 * 0.208 = 19.4	100 * 0.208 = 20.8
Pop. Size	0.075	31 * 0.075 = 2.3	100 * 0.075 = 7.5	77 * 0.075 = 5.8	51 * 0.075 = 3.8
Elderly	0.042	58 * 0.042 = 2.4	100 * 0.042 = 4.2	50 * 0.042 = 2.1	42 * 0.042 = 1.7
Education	0.008	96 * .008 = 0.8	100 * 0.008 = 0.8	97 * 0.008 = 0.8	94 * 0.008 = 0.8
Income	0.125	100 * 0.125 = 12.5	92 * 0.125 = 11.5	86 * 0.125 = 10.8	84 * 0.125 = 10.5
Insured	0.208	100 * 0.208 = 20.8	100 * 0.208 = 20.8	100 * 0.208 = 20.8	99 * 0.208 = 20.7
Composite score		82	87	90	92

TABLE 4.5. SATELLITE CLINIC FACTOR RANKINGS AND MINIMUM ACCEPTABLE LEVELS.

	Zip Codes of Potential Sites					
Factors	**23059**	**23233**	**23112**	**23832**	**Importance Ranking**	**Minimum Acceptable Levels**
Land	\$350,000	\$390,000	\$245,000	\$200,000	3	≤\$350,000
Building	\$450,000	\$450,000	\$435,000	\$425,000	4	≤\$450,000
Operating	\$235,000	\$240,000	\$220,000	\$205,000	2	≤\$225,000
Pop. Size	15,683	50,296	38,660	25,775	6	≥25,000
Elderly	7%	12%	6%	5%	7	≥5%
Education	92%	96%	93%	90%	8	≥90%
Income	\$73,668	\$67,917	\$63,519	\$61,738	5	≥\$60,000
Insured	88%	88%	88%	88%	1	≥85%

Multi-Attribute Methods

As was discussed in Chapter Three, this method allows for metric-free selection decisions using dominance, minimum attribute (factor) satisfaction, and—most important—attribute procedures. To illustrate an application of these procedures to site selection, Table 4.5 lists importance rankings and minimum acceptable levels for each factor for the satellite clinic problem presented earlier in the chapter. A health care manager would make the assessments for each factor, together with his or her analytical team.

Dominance Procedure. Dominance is defined as follows: if an alternative site (X) is at least as good as another alternative (Y) on all attributes and strongly the choice at least on one attribute, then alternative X dominates alternative Y.

As noted earlier, evaluation of alternatives using dominance procedure views one pair of alternatives at a time, so for many alternatives, many pair-wise comparisons have to be completed. In this example, there are four alternatives, so there will be six pair-wise comparisons. To illustrate the dominance, let's take the first pair of alternatives, 23059 versus 23233. Here, on the first factor, "Land," 23059 is better (lower cost); moving on to the second factor, "Building," both alternatives have equal cost (\$450,000); thus we move to the next factor, "Operating," for which 23059 is again better than 23233. "Population size" however, is greater for 23233 than for 23059; hence 23059 is no longer better than 23233. There is no need to evaluate the remaining factors for this pair.

The next pair comparison can be made between 23059 and 23112. This pair has similar results: on the first four factors 23112 is better, but on the fifth factor, elderly, 23059 is better, so we stop the comparison of this pair at this point. Moving to the next pair, 23059 versus 23832, our conclusion is the same; on the fifth factor 23832 loses its dominant position.

The comparison of 23233 and 23112 breaks up on the fourth factor, population size. Similarly, in the 23233 versus 23832 comparison, the advantage of 23832 is lost on the fourth factor. The last pair-wise comparison is of 23112 and 23238, where 23112 breaks the advantage of 23832 on the fourth factor.

Hence, using dominance procedure, we cannot select a site. We cannot even eliminate a site as inferior relative to the others.

Minimum Attribute Satisfaction Procedure. Evaluation of alternatives, especially in site selection, often considers minimum acceptable standards. Therefore, when developing site alternatives, analysts and managers often specify these acceptable standards. Evaluation of alternatives, though, is conducted differently than those in dominance procedure. Here, as we saw in the supplier selection example in Chapter Three, pair-wise comparisons are not used; instead, for each factor all alternatives are considered simultaneously. If any alternative does not meet the minimum acceptable standard satisfactory for a given factor, that alternative is eliminated.

In the ongoing satellite site example, starting with the first factor in Table 4.6, Land, the 23233 site is eliminated since its costs are over $350,000. For the next factor, all remaining sites are satisfactory. For the third factor, site 23059 is eliminated since its operating cost is higher than $225,000. For the remaining factors, both sites have satisfactory scores, so both 23112 and 23832 remain as candidates.

TABLE 4.6. SATELLITE CLINIC FACTOR MINIMUM ACCEPTABLE LEVELS.

	Zip Codes of Potential Sites				
Factors	**23059**	**23233**	**23112**	**23832**	**Minimum Acceptable Level**
Land	$350,000	$390,000	$245,000	$200,000	≤$350,000
Building	$450,000	$450,000	$435,000	$425,000	≤$440,000
Operating	$235,000	$240,000	$220,000	$205,000	≤$225,000
Pop. Size	15,683	50,296	38,660	25,775	≥25,000
Elderly	7%	12%	6%	5%	≥5%
Education	92%	96%	93%	90%	≥90%
Income	$73,668	$67,917	$63,519	$61,738	≥$60,000
Insured	88%	88%	88%	88%	≥85%

TABLE 4.7. SATELLITE CLINIC FACTOR IMPORTANCE RANKINGS.

	Zip Codes of Potential Sites				
Factors	**23059**	**23233**	**23112**	**23832**	**Importance Ranking**
Land	$350,000	$390,000	$245,000	$200,000	3
Building	$450,000	$450,000	$435,000	$425,000	4
Operating	$235,000	$240,000	$220,000	$205,000	2
Pop. Size	15,683	50,296	38,660	25,775	6
Elderly	7%	12%	6%	5%	7
Education	92%	96%	93%	90%	8
Income	$73,668	$67,917	$63,519	$61,738	5
Insured	88%	88%	88%	88%	1

Hence, again, there is no unique solution and other procedures can be applied to obtain one.

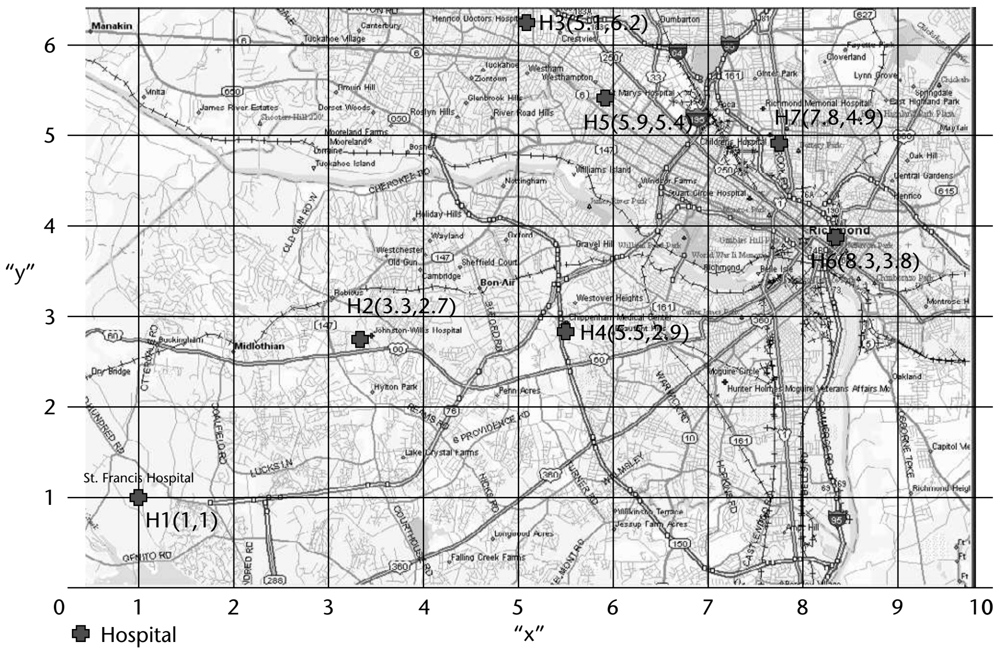
Most Important Attribute Procedure. When the previous procedures yield no solution, this procedure in most instances will. For our site selection example, the importance of the factors (attributes), as developed by the selection team, is shown in Table 4.7.

Like the minimum attribute satisfaction procedure, this one considers all alternatives simultaneously, beginning with the highest-ranking attribute. If the site's scores for that attribute do not point to a solution, analysis moves to the next ranked attribute. The top ranking attribute here is "Insured." Since all four sites have the same score, the health care manager moves on to the second-highest-ranked factor, "Operating," where 23832 has the lowest cost. Now the others are eliminated and site 23832 is the choice.

Center-of-Gravity Method

This method is useful when the geographic position of a location is important in terms of distribution of the services or materials. For instance, a multihospital system may want to locate their supply warehouse in a community or region that will minimize the distribution distance based on the volume of transactions from this warehouse to each hospital or clinic. Similarly, locating a specialty laboratory, a blood bank, or an ambulance service may use this method, which is based on minimum distribution costs. The method works with coordinates on a map and shows existing facilities or communities with respect to the proposed new facility.

FIGURE 4.3. RICHMOND METROPOLITAN AREA HOSPITALS.



Source: Street Atlas USA 8.0, DeLorme, Two DeLorme Drive, P.O. Box 298 Yarmouth, ME 04096.

TABLE 4.8. SELECTED RICHMOND METROPOLITAN AREA HOSPITALS.

Hospital ID	Hospital Name	Coordinates x	Coordinates y
H1	Bon Secours–St. Francis	1.0	1.0
H2	HCA/CJW Medical Center–Johnston Willis	3.3	2.7
H3	HCA/Henrico Doctors	5.1	6.2
H4	HCA/CJW Medical Center–Chippenham Campus	5.5	2.9
H5	Bon Secours–St. Mary's	5.9	5.4
H6	VCU Medical Center	8.3	3.8
H7	Children's Hospital	7.8	4.9

Figure 4.3 displays the map of the Richmond metropolitan area with seven hospitals of interest, using a coordinate system. Using the map coordinates, their positions are identified in Table 4.8.

Let us locate a blood bank supply center that will serve all seven hospitals. First let us assume that the quantities of blood supplies shipped to each hospital (or the number of shipments) are equal. The center-of-gravity location is calculated by taking the average of x and y coordinates, using the following formulas:

$$\bar{x} = \frac{\sum x_i}{n} \quad \text{and} \quad \bar{y} = \frac{\sum y_i}{n} \qquad [4.10]$$

where

$\bar{x}$ = x coordinate of blood bank
$\bar{y}$ = y coordinate of blood bank
x_i = x coordinate of hospital i
y_i = y coordinate of hospital i
n = number of hospitals
x = x coordinate of blood bank
y = y coordinate of blood bank.

For the blood bank example:

$$\bar{x} = \frac{1.0 + 3.3 + 5.1 + 5.5 + 5.9 + 8.3 + 7.8}{7} = \frac{36.9}{7} = 5.3$$

$$\bar{y} = \frac{1.0 + 2.7 + 6.2 + 2.9 + 5.4 + 3.8 + 4.9}{7} = \frac{26.9}{7} = 3.8.$$

Hence, the blood bank can be located at coordinates 5.3, 3.8, north of H4 (CJW-Chippenham campus).

In reality, of course, the blood bank's interactions with each hospital will not be the same. In Table 4.9 yearly shipments from the blood bank to each hospital are identified as Q. Inclusion of the frequency of activity between the blood bank

TABLE 4.9. SELECTED RICHMOND METROPOLITAN AREA HOSPITALS AND THEIR INTERACTION WITH THE BLOOD BANK.

Hospital ID	Hospital Name	Coordinates *x*	Coordinates *y*	Yearly Shipments *Q*
H1	Bon Secours–St. Francis	1.0	1.0	460
H2	HCA/CJW Medical Center–Johnston Willis	3.3	2.7	470
H3	HCA/Henrico Doctors	5.1	6.2	250
H4	HCA/CJW Medical Center–Chippenham Campus	5.5	2.9	480
H5	Bon Secours–St. Mary's	5.9	5.4	320
H6	VCU Medical Center	8.3	3.8	700
H7	Children's Hospital	7.8	4.9	120

and hospitals can be formulated using a weighted average formula as follows:

$$\bar{x} = \frac{\sum x_i Q_i}{\sum Q_i} \quad \text{and} \quad \bar{y} = \frac{\sum y_i Q_i}{\sum Q_i}. \qquad [4.11]$$

Weighted average solution for blood bank would be:

$$\bar{x} = \frac{1.0(460) + 3.3(470) + 5.1(250) + 5.5(480) + 5.9(320) + 8.3(700) + 7.8(120)}{460 + 470 + 250 + 480 + 320 + 700 + 120}$$

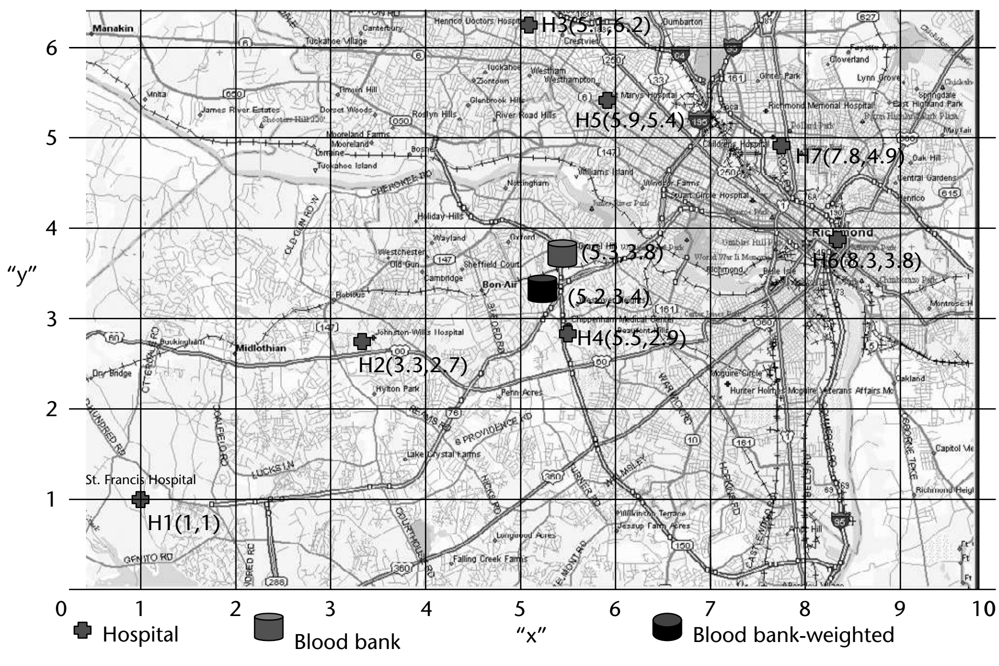
$$= \frac{14{,}560}{2800} = 5.2$$

$$\bar{y} = \frac{1.0(460) + 2.7(470) + 6.2(250) + 2.9(480) + 5.4(320) + 3.8(700) + 4.9(120)}{460 + 470 + 250 + 480 + 320 + 700 + 120}$$

$$= \frac{9{,}647}{2{,}800} = 3.4.$$

When the number of shipments are considered, the location of the blood bank moves slightly southwest. Figure 4.4 depicts both nonweighted and weighted solutions to the blood bank location.

FIGURE 4.4. RICHMOND METROPOLITAN AREA BLOOD BANK LOCATIONS.



Source: Street Atlas USA 8.0, DeLorme, Two DeLorme Drive, P.O. Box 298 Yarmouth, ME 04096.

FIGURE 4.5. WINQSB SETUP AND SOLUTION TO BLOOD BANK PROBLEM.

Facility Name	To Existing 1 Flow/Unit Cost	To Existing 2 Flow/Unit Cost	To Existing 3 Flow/Unit Cost	To Existing 4 Flow/Unit Cost	To Existing 5 Flow/Unit Cost	To Existing 6 Flow/Unit Cost	To Existing 7 Flow/Unit Cost	To New 1 Flow/Unit Cost	Location X Axis	Location Y Axis
H1								460	1	1
H2								470	3.3	2.7
H3								250	5.1	6.2
H4								480	5.5	2.9
H5								320	5.9	5.4
H6								700	8.3	3.8
H7								120	7.8	4.9
BB										

Blood Bank Location

07-24-2004 11:12:46	Facility Name	X Axis	Y Axis	Flow To All Facilities	Cost To All Facilities
1	H1	1	1	460	10,865.09
2	H2	3.30	2.70	470	1,957.81
3	H3	5.10	6.20	250	1,899.51
4	H4	5.50	2.90	480	185.96
5	H5	5.90	5.40	320	1,379.40
6	H6	8.30	3.80	700	6,815.04
7	H7	7.80	4.90	120	1,065.12
8	BB	5.20	3.45	0	0
	Total			2800	24,167.94
	Distance	Measure:	Squared	Euclidian	

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

Software Solution Using WinQSB

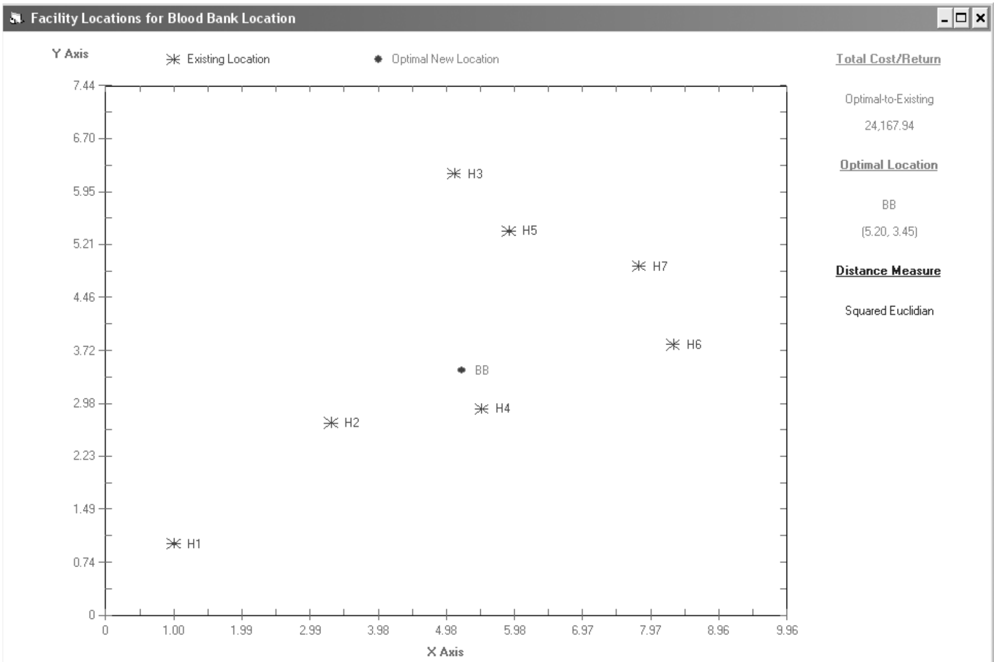
Figures 4.5 and 4.6 display the setup and the solution to the blood bank location problem. (Note: To obtain the same results in WinQSB, Squared Euclidian Distance option should be selected. For nonweighted solution, a value of 1 should be used as a weight for each location).

Geographic Information Systems (GIS) in Health Care

Geographic information systems are valuable tools for storing, integrating, and displaying data for specific geographic areas. Health care managers can use color-coded map systems indicating the levels and types of disease and analyze the associated data on utilization and the potential for health care business in the area. GIS are excellent starting points to identify potential markets for new product lines, and are used by other service industries such as banks, retailers, and restaurants.

Health services researchers have been studying and applying GIS for a decade. The Dartmouth Atlas of Health Care, developed by Dartmouth Medical School, provides information helpful to health care businesses of many sorts, including primary care (Goodman and others, 2003). Most notably, National Cancer Institute

FIGURE 4.6. WINQSB GRAPHICAL SOLUTION TO BLOOD BANK PROBLEM.



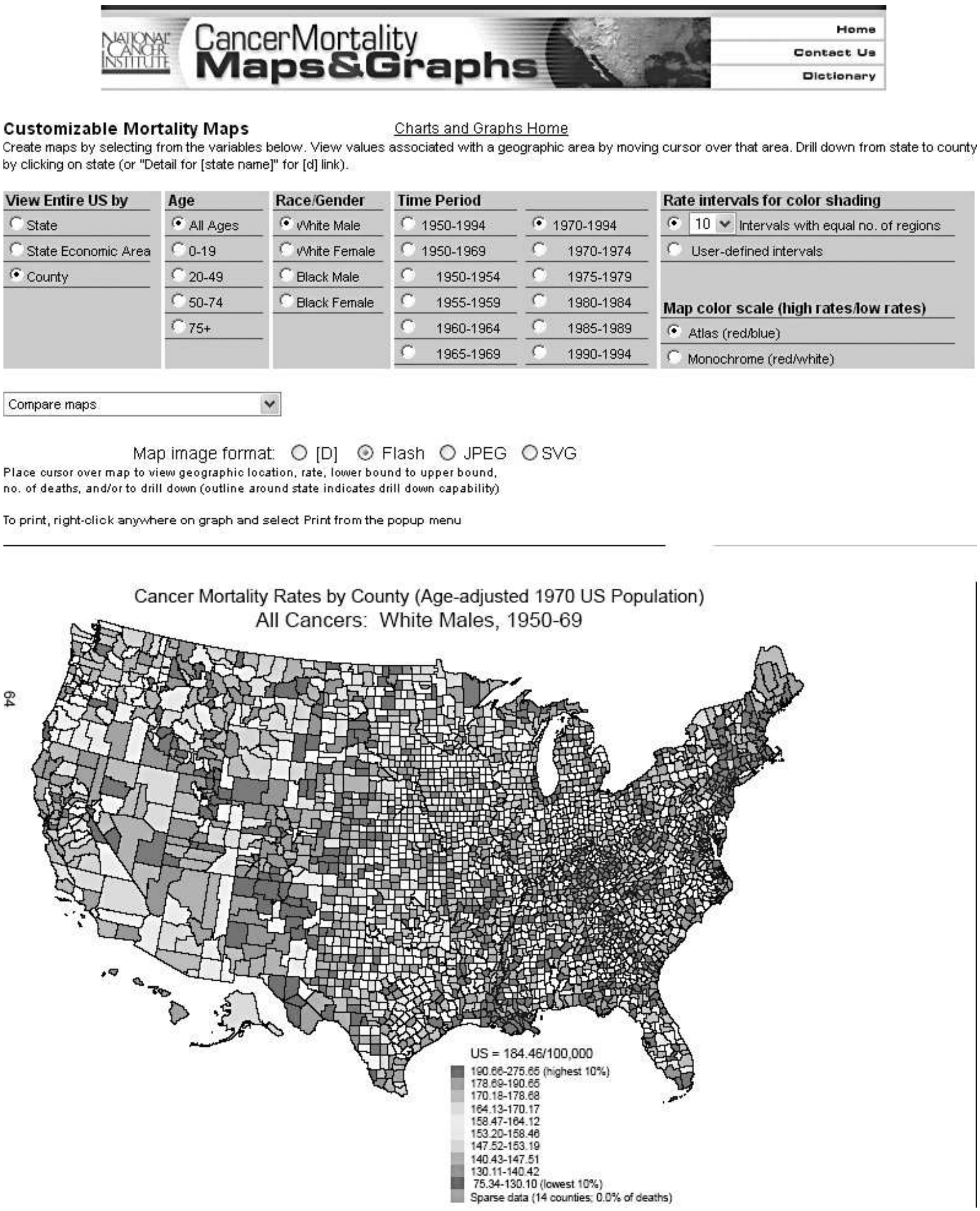
Source: Screen shots reprinted by permission from Microsoft Corporation and Yih-Long Chang (author of WinQSB).

provides customizable maps at state and county levels for various cancer mortality rates by gender and age-specific groups. The Web site http://www3.cancer.gov/atlas also provides comparative geographic analysis in five-year slices. As an example, Figure 4.7 displays county-level cancer mortality rates for the entire United States for white males of all ages, from 1950 to 1969. Using this information, health care managers can develop new service lines or adjust the current offerings for their service areas.

Summary

In this chapter, a discussion of reasons that prompt health care managers to consider new locations for health care facilities is provided. The methodology of location site selection depends on a particular problem and available data. A

FIGURE 4.7. GEOGRAPHIC INFORMATION SYSTEMS.



Source: National Cancer Institute.

portfolio of site selection methods: cost-profit-volume analysis, factor rating methods, and center-of-gravity method and their use were offered as potential tools to health care managers.

Exercises

Exercise 4.1

An independent MRI services company wishes to expand their present operation by adding another center. Four locations have been studied. Each potential site would have the same labor and materials costs, of $200 per procedure. The MRIs generate revenue of $375 irrespective of location. Rental and equipment costs per year for the four sites are as follows:

Location A: $525,000
Location B: $585,000
Location C: $480,000
Location D: $610,000.

a. Determine the volume necessary at each location to realize $2,000,000 in profits, and which location is the most likely candidate.
b. If the expected volumes of MRIs are, respectively, 15,500, 20,200, 18,300 and 19,200 for locations A, B, C, and D, which location should be chosen?

Exercise 4.2

A Doc-in-a-Box office, a group of family practitioners, is looking for a new location to expand their services. Three locations are identified, with fixed costs. Because of diverse population profiles in each location, patient visits, variable costs, and revenues vary in each location as shown in Table EX 4.2.

TABLE EX 4.2.

	A	B	C
Average revenue per patient	47	60	58
Average variable cost per patient	37	47	45
Average number of visits	13,500	12,000	11,500
Fixed costs in $	120,000	145,000	140,000

a. Determine the location based on total cost.
b. Determine the location based on revenue.
c. Determine the location based on profit.
d. Determine the sensitivity of the decision in "c" varying values of visits (Hint: draw a graph of cost, revenue and profit).

Exercise 4.3

Urology Associates (UA), a group practice, is seeking expansion of their services to other regions. A health care analyst evaluated six factors to be considered by UA for three locations, as shown in Table EX 4.3.

TABLE EX 4.3.

		Location		
Factors	**Weight**	**I**	**II**	**III**
Access	0.15	80	70	60
Parking	0.25	90	76	72
Building	0.15	88	90	89
Population density	0.25	94	94	80
Operating costs	0.10	98	90	82
Proximity of other health care offices	0.10	96	75	75

Factor scores are based on 0–100 points.

Determine the new UA location based on the three possibilities' composite factor scores.

Exercise 4.4

WE RESCUE, Inc., a firm providing nationwide ambulance services, intends to expand its service range through a new branch in the suburbs of the mid-Atlantic region. The data were gathered to evaluate three different possible sites: Suburb A, Suburb B, and Suburb C, for the new location. The data include factor ratings, minimum satisfactory level, and importance rankings of each factor (attribute), as shown in Table EX 4.4.

TABLE EX 4.4.

Attributes (factors)	**Weights**	**Suburb A**	**Suburb B**	**Suburb C**	**Minimum Satisfaction Level**	**Importance Ranking**
Contracting and land cost	0.1	65*	76	45	70	3
Labor availability and costs	0.15	50	65	60	65	5
Transportation and road network	0.15	60	70	75	80	4
Suppliers/supporting service companies	0.13	75	60	65	85	6
Average time per emergency trip	0.22	95	75	70	95	2
Accessibility to hospital	0.18	85	80	65	90	1
Employee preferences	0.07	60	50	55	75	7
Total	1.00					

(*continued*)

TABLE EX 4.4. (Continued)

Attributes (factors)	Weights	Suburb A	Suburb B	Suburb C	Minimum Satisfaction Level	Importance Ranking
Average revenue per patient visit		50	40	45		
Patient volume		20,000	20,000	20,000		
Fixed cost		200,000	300,000	250,000		
Avg. variable cost per patient		25	18	20		

Factor scores are based on 0–100 points.

a. Decide which location should be chosen for a new ambulance service location, on the basis of the alternatives' maximum composite score.
b. Determine whether any location dominates the others.
c. Choose a location based on the minimum satisfaction procedure alone.
d. Choose a location based on the most important attribute procedure alone.
e. Choose a location based on cost-volume analysis.
f. After all the analyses above, which location would you support, and why?

Exercise 4.5

A contract dispute with the landlord prompted a multichain hospital to reconsider and optimize the location of their regional warehouse for medical supply materials to minimize the time for deliveries to their twelve hospitals in the region. The current warehouse is located at ($x = 3$, $y = 3$). The coordinates of the hospitals in the region are given in Table EX 4.5.

TABLE EX 4.5.

Hospitals	*x*	*y*
H1	3	7
H2	9	4
H3	6	9
H4	3	9
H5	8	2
H6	4	1
H7	6	4
H8	5	7
H9	1	8
H10	4	6
H11	10	5
H12	12	3

a. Draw a map showing the positions of the current warehouse and hospitals.
b. Determine the new location of warehouse using the center-of-gravity method.

Exercise 4.6

The hospitals identified in Exercise 4.5 are in varying sizes, so the need for medical supplies varies, which affects the number of deliveries for each. The health care supply chain manager determined the number of trips per year to each hospital, as shown in Table EX 4.6.

TABLE EX 4.6.

Hospitals	Number of Deliveries
H1	230
H2	280
H3	345
H4	112
H5	235
H6	405
H7	90
H8	370
H9	189
H10	405
H11	109
H12	130

Determine the new location of the warehouse, using the weighted center-of-gravity method.