Chapter six

FACILITY LOCATION

6-1- Introduction

Plant location or the facilities location problem is an important strategic level decision-making for an organization. One of the key features of a conversion process (manufacturing system) is the efficiency with which the products (services) are transferred to the customers. This fact will include the determination of where to place the plant or facility.

*The selection of location is a key-decision as large investment is made in building plant and machinery.* It is not advisable or not possible to change the location very often. *So an improper location of plant may lead to waste of all the investments made in building and machinery, equipment.*

Before a location for a plant is selected, *long range forecasts* should be made *anticipating future needs of the company.* The plant location should be *based on the company’s expansion plan and policy, diversification plan for the products, changing market conditions, the changing sources of raw materials and many other factors that influence the choice of the location decision.* The purpose of the location study is to find an optimum location one that will result in the greatest advantage to the organization.

6-2- THE NEED FOR SELECTING A SUITABLE LOCATION

The need for selecting a suitable location arises because of three situations.

I. When starting a new organization, i.e., location choice for the first time.

II. In case of existing organization.

III. In case of Global Location.
It is appropriate to divide the factors, which influence the plant location or facility location on the basis of the nature of the organization as:

1. General locational factors, which include controllable and uncontrollable factors for all type of organizations.

2. Specific locational factors specifically required for manufacturing and service organizations.

*Location factors can be further divided into two categories:*

**Dominant factors** are those derived from *competitive priorities (cost, quality, time, and flexibility)* and have a particularly strong impact on sales or costs. **Secondary factors** also are important, *but management may downplay or even ignore some of them if other factors are more important.*

**General Locational Factors**

Following are the general factors required for location of plant in case of all types of organizations.

**6-3- CONTROLLABLE FACTORS**

1. **Proximity to markets:** it is advisable to locate the facilities close to the market.

Locating nearer to the market is preferred if:

- The products are delicate and susceptible to spoilage.
- After sales services are promptly required very often.
- Transportation cost is high and increase the cost significantly.
- Shelf life of the product is low.

*Nearness to the market ensures a consistent supply of goods to customers and reduces the cost of transportation.*

2. **Supply of materials:** It is essential for the organization to get raw material in right qualities and time in order to have an uninterrupted production. General guidelines effects of raw materials on plant location are:
• When a single raw material is used without loss of weight, locate the plant at the raw material source, at the market or at any point in between.

• When weight loosing raw material is demanded to locate the plant at the raw material source.

• When raw material is universally available, locate close to the market area.

• If the raw materials are processed from variety of locations, the plant may be situated so as to minimize total transportation costs.

Nearness to raw material is important in case of industries such as sugar, cement, jute and cotton textiles.

3. Transportation facilities: Speedy transport facilities ensure timely supply of raw materials to the company and finished goods to the customers. The transport facility is a prerequisite for the location of the plant. There are five basic modes of physical transportation, air, road, rail, water and pipeline. Goods that are mainly intended for exports demand a location near to the port or large airport. The choice of transport method and hence the location will depend on relative costs, convenience, and suitability. Thus transportation cost to value added is one of the criteria for plant location.

4. Infrastructure availability: The basic infrastructure facilities like power, water and waste disposal, etc., Certain types of industries are power hungry e.g., aluminum and steel and they should be located close to the power station or location where uninterrupted power supply is assured throughout the year. The non-availability of power may become a survival problem for such industries. Process industries like paper, chemical, cement, etc., require continuous. Supply of water in large amount and good quality, and mineral content of water becomes an important factor. A waste disposal facility for process industries is an important factor, which influences the plant location.

5. Labour and wages: The problem of securing adequate number of labour and with skills specific is a factor to be considered both at territorial as well as at community level during plant location. Importing labour is usually costly and involve administrative problem.
6. **External economies of scale**: External economies of scale can be described as urbanization and locational economies of scale. It refers to advantages of a company by setting up operations in a large city while the second one refers to the “settling down” among other companies of related Industries. In the case of urbanization economies, firms derive from locating in larger cities rather than in smaller ones in a search of having access to a large pool of labour, transport facilities, and as well to increase their markets for selling their products and have access to a much wider range of business services.

Location economies of scale in the manufacturing sector have evolved over time and have mainly increased competition due to production facilities and lower production costs as a result of lower transportation and logistical costs. This led to manufacturing districts where many companies of related industries are located more or less in the same area.

7. **Capital**: By looking at capital as a location condition, it is important to distinguish the physiology of fixed capital in buildings and equipment from financial capital. Fixed capital costs as building and construction costs vary from region to region. But on the other hand buildings can also be rented and existing plants can be expanded. Financial capital is highly mobile and does not very much influence decisions.

**6-4- UNCONTROLLABLE FACTORS**

8. **Government policy**: The policies of the state governments and local bodies concerning labour laws, building codes, safety, etc., are the factors that demand attention.

9. **Climatic conditions**: The geology of the area needs to be considered together with climatic conditions (humidity, temperature). Climates greatly influence human efficiency and behavior. Some industries require specific climatic conditions e.g., textile mill will require humidity.

10. **Supporting industries and services**: the source of supply of component parts will be the one of the factors that influences the location.
The various services like communications, banking services professional consultancy services and other civil amenities services will play a vital role in selection of a location.

11. **Community and labour attitudes**: Community attitude towards their work and towards the prospective industries can make or mar the industry. Community attitudes towards supporting trade union activities are important criteria. Facility location in specific location is not desirable even though all factors are favouring because of labour attitude towards management, which brings very often the strikes and lockouts.

12. **Community infrastructure and amenity**: All manufacturing activities require access to a community infrastructure, most notably economic overhead capital, such as roads, railways, port facilities, power lines and service facilities and social overhead capital like schools, universities and hospitals.

These factors are also needed to be considered by location decisions as infrastructure is enormously expensive to build and for most manufacturing activities the existing stock of infrastructure provides physical restrictions on location possibilities.

**6-5- LOCATION MODELS**

Various models are available which help to identify the ideal location. Some of the popular models are:

1. Factor rating method
2. Weighted factor rating method
3. Load-distance method
4. Centre of gravity method
5. Break-even analysis.
6.5.1 Factor Rating Method

The process of selecting a new facility location involves a series of following steps:

1. Identify the important location factors.

2. Rate each factor according to its relative importance, i.e., higher the ratings is indicative of prominent factor.

3. Assign each location according to the merits of the location for each factor.

4. Calculate the rating for each location by multiplying factor assigned to each location with basic factors considered.

5. Find the sum of product calculated for each factor and select best location having highest total score.

Example- 6-1: Let us assume that a new medical facility, Health-care, is to be located in Delhi. The location factors, factor rating and scores for two potential sites are shown in the following table. Which is the best location based on factor rating method?

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Location factor</th>
<th>Factor rating</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Location 1</td>
</tr>
<tr>
<td>1</td>
<td>Facility utilization</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>Total patient per month</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>Average time per emergency trip</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>Land and construction costs</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Employee preferences</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>
SOLUTION:

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Location factor</th>
<th>Factor rating (1)</th>
<th>Location 1 (Rating) (2)</th>
<th>Total = (1) . (2)</th>
<th>Location 2 (Rating) (3)</th>
<th>Total = (1) . (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Facility utilization</td>
<td>8</td>
<td>3</td>
<td>24</td>
<td>5</td>
<td>40</td>
</tr>
<tr>
<td>2.</td>
<td>Total patient per month</td>
<td>5</td>
<td>4</td>
<td>20</td>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td>3.</td>
<td>Average time per emergency trip</td>
<td>6</td>
<td>4</td>
<td>24</td>
<td>5</td>
<td>30</td>
</tr>
<tr>
<td>4.</td>
<td>Land and construction costs</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>5.</td>
<td>Employee preferences</td>
<td>5</td>
<td>5</td>
<td>25</td>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td></td>
<td></td>
<td>96</td>
<td></td>
<td>106</td>
</tr>
</tbody>
</table>

The total score for location 2 is higher than that of location 1. Hence location 2, is the best choice.

6.5.2 Weighted Factor Rating Method

In this method to merge quantitative and qualitative factors, factors are assigned weights based on relative importance and weightage score for each site using a preference matrix is calculated. The site with the highest weighted score is selected as the best choice.

Example 6-2: Let us assume that a new medical facility, Health-care, is to be located in Delhi. The location factors, weights, and scores (1 = poor, 5 = excellent) for two potential sites are shown in the following table. What is the weighted score for these sites? Which is the best location?
**SOLUTION:** The weighted score for this particular site is calculated by multiplying each factor’s weight by its score and adding the results:

<table>
<thead>
<tr>
<th>No.</th>
<th>Location factor</th>
<th>Weight</th>
<th>Location 1</th>
<th>Location 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Facility utilization</td>
<td>25</td>
<td>3 x 25= 75</td>
<td>125</td>
</tr>
<tr>
<td>2</td>
<td>Total patient per month</td>
<td>25</td>
<td>4x 25= 100</td>
<td>75</td>
</tr>
<tr>
<td>3</td>
<td>Average time per emergency trip</td>
<td>25</td>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td>4</td>
<td>Land and construction costs</td>
<td>15</td>
<td>15</td>
<td>30</td>
</tr>
<tr>
<td>5</td>
<td>Employee preferences</td>
<td>10</td>
<td>50</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td></td>
<td><strong>315</strong></td>
<td><strong>335</strong></td>
</tr>
</tbody>
</table>

Location 2 is the best site based on total weighted scores.

**6.5.3 Load-distance Method**

The load-distance method is a mathematical model used to evaluate locations based on proximity factors. The objective is to select a location that minimizes the total weighted loads moving into and out of the facility. The distance between two points is expressed by assigning the points to grid coordinates on a map. An alternative approach is to use time rather than distance.

![Fig. 6.2 Distance between point A and point B](image)

The point A on the grid represents the supplier’s location in G-city, and the point B represents the possible warehouse location at K-city. The distance between points A and B is the length of the hypotenuse of a right triangle, or
Rectilinear distance measures distance between two points with a series of 90° turns as city blocks. Essentially, this distance is the sum of the two dashed lines representing the base and side of the triangle in figure. The distance travelled in the x-direction is the absolute value of the difference in x-coordinates. Adding this result to the absolute value of the difference in the y-coordinates gives

\[ D_{AB} = |X_A - X_B| + |Y_A - Y_B| \]

- Step 1: identify distances
- Step 2: identify loads
- Step 3: calculate the load-distance score for each location

For load-distance method, a rough calculation that is either Euclidean or rectilinear distance measure may be used. Euclidean distance is the straight-line distance, or shortest possible path, between two points.

**Example 6-3**: The new service facility is targeted to serve seven sell agencies in Delhi. The table - shows the coordinates for the centre of each sell agency, along with the projected populations, measured in thousands. Customers will travel from the seven sell agencies centers to the new facility when they need that. Two locations being considered for the new facility are at (5.5, 4.5) and (7, 2), which are the centers of sell agency C and F. Details of seven sell agencies centers, coordinate distances along with the population for each centre are given too. Use the population as the loads and use rectilinear distance, which location is better in terms of its total load-distance score?
Solution:

<table>
<thead>
<tr>
<th>Sell agency</th>
<th>Sites coordination (x,y)</th>
<th>populations</th>
<th>Locate at (5.5, 4.5)</th>
<th>Locate at (7, 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Distance (d)</td>
<td>Load-distance</td>
<td>Distance (d)</td>
</tr>
<tr>
<td>A</td>
<td>(2.5, 4.5)</td>
<td>2</td>
<td>3 + 0 = 3</td>
<td>6</td>
</tr>
<tr>
<td>B</td>
<td>(2.5, 2.5)</td>
<td>5</td>
<td>3 + 2 = 5</td>
<td>25</td>
</tr>
<tr>
<td>C*</td>
<td>(5.5, 4.5)</td>
<td>10</td>
<td>0 + 0 = 0</td>
<td>0</td>
</tr>
<tr>
<td>D</td>
<td>(5, 2)</td>
<td>7</td>
<td>0.5 + 2.5 = 3</td>
<td>21</td>
</tr>
<tr>
<td>E</td>
<td>(8, 5)</td>
<td>10</td>
<td>2.5 + 0.5 = 3</td>
<td>30</td>
</tr>
<tr>
<td>F*</td>
<td>(7, 2)</td>
<td>20</td>
<td>1.5 + 2.5 = 4</td>
<td>80</td>
</tr>
<tr>
<td>G</td>
<td>(9, 2.5)</td>
<td>14</td>
<td>3.5 + 2 = 5.5</td>
<td>77</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total</td>
<td>239</td>
<td>Total</td>
</tr>
</tbody>
</table>

Summing the scores for all centers gives a total load-distance score of 239 when the facility is located at (5.5, 4.5) versus a load-distance score of 168 at location (7, 2). Therefore, the location in F is a better location.
6.5.4 Centre of Gravity

Centre of gravity is based primarily on cost considerations. This method can be used to assist managers in balancing cost and service objectives. The centre of gravity method takes into account the locations of plants and markets, the volume of goods moved, and transportation costs in arriving at the best location for a single intermediate warehouse.

The centre of gravity is defined to be the location that minimizes the weighted distance between the warehouse and its supply and distribution points, where the distance is weighted by the number of tones supplied or consumed. The first step in this procedure is to place the locations on a coordinate system. The origin of the coordinate system and scale used are arbitrary, just as long as the relative distances are correctly represented. This can be easily done by placing a grid over an ordinary map. The centre of gravity is determined by the formula. Two sites A and B are evaluated in terms of above mentioned two costs as follows:

\[
C_x = \frac{\sum D_{ix} W_i}{\sum W_i} \quad \quad C_y = \frac{\sum D_{iy} W_i}{\sum W_i}
\]

where

- \( C_x \) = x-coordinate of the centre of gravity
- \( C_y \) = y-coordinate of the centre of gravity
- \( D_{ix} \) = x-coordinate of location \( i \)
- \( D_{iy} \) = y-coordinate of location \( i \)

**Example 6-4:** A famous restaurant chain purchases ingredients from four different food suppliers. The company wants to construct a new central distribution center to process and package the ingredients before shipping them to their various restaurants. The suppliers transport ingredient items in 40-foot truck trailers, each with a capacity of 38,000 pounds. The locations of the four suppliers, A, B, C, and D, and the annual number of trailer loads that will be transported to the distribution center are shown in the following figure:
Fig. 6-3 shows the annual number of trailer loads that will be transported to the distribution center.

Using the center-of-gravity method, determine a possible location for the distribution center.

**SOLUTION:** 1- arrange a table of the given data, 2-use the equations:

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>$x_A$</td>
<td>200</td>
<td>$x_B$</td>
<td>100</td>
<td>$x_C$</td>
</tr>
<tr>
<td>$y_A$</td>
<td>200</td>
<td>$y_B$</td>
<td>500</td>
<td>$y_C$</td>
</tr>
<tr>
<td>$w_A$</td>
<td>75</td>
<td>$w_B$</td>
<td>105</td>
<td>$w_C$</td>
</tr>
</tbody>
</table>
Thus, the suggested coordinates for the new distribution center location are $x = 238$ and $y = 444$. However, it should be kept in mind that these coordinates are based on straight-line distances, and in a real situation actual roads might follow more circuitous routes.

**Question 1:** The new service facility is targeted to serve seven sell agencies in Delhi. The table shows the coordinates for the centre of each sell agency, along with the projected populations, measured in thousands. Customers will travel from the seven sell agencies centers to the new facility when they need that. Two locations being considered for the new facility are at $(5.5, 4.5)$ and $(7, 2)$, which are the centers of sell agency C and F. Details of seven sell agencies centers, coordinate distances along with the population for each centre are given too. Find the target area’s centre of gravity for the service facility.

<table>
<thead>
<tr>
<th>No. #</th>
<th>Sell agency</th>
<th>Site ordinations (x,y)</th>
<th>populations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A</td>
<td>(2.5, 4.5)</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>B</td>
<td>(2.5, 2.5)</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>C</td>
<td>(5.5, 4.5)</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>D</td>
<td>(5, 2)</td>
<td>7</td>
</tr>
<tr>
<td>5</td>
<td>E</td>
<td>(8, 5)</td>
<td>10</td>
</tr>
<tr>
<td>6</td>
<td>F</td>
<td>(7, 2)</td>
<td>20</td>
</tr>
<tr>
<td>7</td>
<td>G</td>
<td>(9, 2.5)</td>
<td>14</td>
</tr>
</tbody>
</table>
### 6.5.5 Break-even Analysis

Break even analysis implies that at some point in the operations, total revenue equals total cost. Break even analysis is concerned with finding the point at which revenues and costs agree exactly. It is called ‘Break-even Point’. The Fig. 6.3 portrays the Break Even Chart:

*Break-even point is the volume of output at which neither a profit is made nor a loss is incurred.*

The Break Even Point (BEP) in units can be calculated by using the relation:

\[
\text{BEP} = \frac{\text{Fixed Cost}}{\text{Contribution per unit}} = \frac{\text{Fixed Cost}}{\text{Selling Price} - \text{Variable Cost per unit}} = \frac{F}{S - V} \text{ units}
\]

![Break Even Chart](image)

Fig. 6.4 Units of output or percentage of capacity

\[
\text{BEP} = \frac{\text{Fixed Cost}}{\text{Sales} - \text{Variable Cost}}
\]

\[
\text{Fixed Cost}
\]
Plotting the break even chart for each location can make economic comparisons of locations. This will be helpful in identifying the range of production volume over which location can be selected.

**Example 6-5:** The ABC company has a demand of 1,30,000 units of a new product. Three potential locations X, Y and Z having following cost structures shown are available. Select which location is to be selected and also identify the volume ranges where each location is suited?

<table>
<thead>
<tr>
<th>Location</th>
<th>Fixed Costs - $</th>
<th>Variable Costs- $</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location X</td>
<td>150000</td>
<td>10</td>
</tr>
<tr>
<td>Location Y</td>
<td>350000</td>
<td>8</td>
</tr>
<tr>
<td>Location Z</td>
<td>950000</td>
<td>6</td>
</tr>
</tbody>
</table>

**SOLUTION:** at BEP, for the same production quantity or volume, we get:

Solve for the crossover between X and Y:

\[ 10Q + 150,000 = 8Q + 350,000 \]
\[ 2Q = 200,000 \]
\[ Q = 100,000 \text{ units} \]

Solve for the crossover between Y and Z:

\[ 8Q + 350,000 = 6Q + 950,000 \]
\[ 2Q = 600,000 \]
\[ Q = 300,000 \text{ units} \]

Therefore, at a volume of 1,30,000 units, Y is the appropriate strategy.

From the graph (Fig. 6.4) we can interpret that location X is suitable up to 100,000 units, location Y is suitable up to between 100,000 to 300,000 units and location Z is suitable if the demand is more than 300,000 units.
Fig. 6.5  BEP chart