Part—I
Plant Layout

1
PLANT LOCATION

1.1. INTRODUCTION

Location of an industry is an important management decision. It is a two-step decision, first choice of general area or region and second choice of site within the area selected. Location decision is based on the organisation's long-term strategies such as technological, marketing, resource availability, and financial strategies.

The objective of plant location decision-making is to minimise the sum of all costs affected by location.

Plant location is important because of the following :

(*i*) Location influences plant layout facilities needed, and

(*ii*) Location influences capital investment and operating costs.

Location decisions are strategic, long-term and non-repetitive in nature. Without sound and careful location planning in the beginning itself, the new facility may create continuous operating problems in future. Location decision also affects the efficiency, effectiveness, productivity and profitability.

Traditionally, location aspect deals with industrial plant *i.e.,*factory location, but now-a-days when service sector is gaining importance and requires technological advanced applications, the concept of **plant location** has been generalised into that of **facility location.** Here facility includes a production operation and service system. The term **'plant'** is traditionally used as synonymous to a factory, manufacturing or assembling unit. However, with the enlarged scope of facility the term include service organisations. Here in the book, both the terms have been used for factory with service centers including machines, equipment, workshop, office etc.

1.1.1. Facility Planning

Facility planning (land, buildings, equipment, furnishings) provides the physical capability to add value may be through manufacturing, service, transport etc. Since the facilities are expensive, their life time is in decades, take years to commission, and by nature, they are one of the most important strategic elements of a business

enterprise. Therefore facility design and the strategic thinking that should precede it are very important.

A properly designed facility is an important source of competitive advantage are :

- Operate at low cost.
- Provide fast delivery.
- Accommodate new products.
- Produce many varied products.
- Increase or decrease volume of production.
- Provide unique service or features.
- Produce at the highest quality level.

Facility planning should be carried out in following stages :

Stage I – Site location.

Stage II – Site planning.

Stage III – Building layout.

Stage IV – Department layout.

Stage V – Work-station design.

Need for location decision arises in following circumstances :

(1) When a new facility to be established?

(2) Expansion of existing facility.

(3) To establish additional facilities in new territories due to growing volume of business.

(4) When original advantages of the plant have been outweighed due to new developments?

(5) When new economic, social, legal or political factors suggest a change of location of the existing facility?

The location decision should be taken very carefully, as any mistake may cause poor location, which could be a constant source of higher cost, higher investment, difficult marketing and transportation, dissatisfied and frustrated employees and consumers, frequent interruptions of production, abnormal wastages, delays and substandard quality etc.

Therefore, it should be based upon a careful consideration of all factors that are essentially needed in efficient running of a particular industry. The necessary factors in the selection of plant location vary among industries and with changing technical and economical conditions.

1.2. SITE SELECTION

Site selection is not an easy problem because if the selection is not proper then all money spent on factory building, machinery and their installation etc. will go as waste and the owner has to suffer a great loss. Therefore, while selecting a site, owner must consider technical, commercial, financial aspects which may provide maximum advantages. It is sometimes possible that all the requirements and features of ideal site may not be available at one particular location but then it will be advantageous to find out suitable site with combinations of all essential requirements of the particular industry to be established as explained in following paras :

The problem of the selection of site for a factory or a plant can be solved in the following two stages :

- The general location of the plant.
- The selection of a particular site.

1.2.1. The General Location of the Plant

Following factors must be considered for selecting a region where the factory is to be located :

(*i*) *Availability of Raw Materials.* As far as possible, the site selected should be near the source or raw materials, so that the cost of transporting the raw materials to the plant may be minimum. Further, if the raw materials are bulky and heavy, it becomes very essential to select the site near it.

This is the main reason that early localisation of most of the iron and steel industries in Orissa and Jharkhand is basically due to the proximity to raw-materials.

Again, if the raw materials are perishable, as sugarcane, proximity to supply of raw materials is an advantage. Hence most of the sugar factories in Maharashtra and Uttar Pradesh are situated in areas growing sugarcane.

(*ii*) *Proximity to Markets.* The cost of transporting finished goods, advertising and distribution, etc. will be greatly reduced if the factory is situated near the market. Secondly, it will help in quick service to the customers and their requirements can also be studied quickly and easily.

(*iii*) *Transport Facilities.* Transportation cost of raw material plays an important role, specially when the raw material are bulky and of low value. Therefore, most of the iron, coal and other heavy chemical industries are located at the raw material centres.

Similarly when finished product is heavy, nearness to the market is economical.

With the development of highway infrastructural facilities, road transport has become a successful competitor of rail-transport on account of the advantage of quickness and convenience of door to door service and lead to the location of some of the new factories on the roadside.

(*iv*) *Availability of Efficient and Cheap Labour.* While selecting a site, it is necessary to consider that whether right kind of labour at suitable rates is available or not, because labour cost is an important item of the total production cost in manufacturing.

The famous glass and bangle industries at Firozabad, that of woollen carpets at Mirzapur and silk sarees at Varansi/Kanziwaram (Tamilnadu), etc. are mainly due to the highly skilled labour for that particular industry available at these places.

(*v*) *Availability of Power and Fuel.* In the past, the industries were situated near coal mines or places to which coal could be carried easily and cheaply. But due to development of high tension grid system this factor is not of much importance now.

(*vi*) *Climatic and Atmospheric Conditions.* It is a governing factor for several industries, as cotton industry require moist climate that is why, most of the textile mills have been located at Mumbai and Ahmedabad. But nowadays with the development of air-conditioning process, it has been possible to control the atmospheric moisture contents in the factory according to the requirements.

(*vii*) *Availability of Water.* Certain factories need large quantity of water, hence it should be ascertained that sufficient water is available.

(*viii*) *Availability of Capital.* The supply of capital is an important factor on the rate of development of a factory. Amount of capital available helps in determining the size of the plant and its future plans.

(*ix*) *Social and Recreational Facilities.* Usually big factories are located away from the urban areas. During off hours, the employees require some social and recreational amenities which are the necessities of life. Therefore, it is essential that suitable parks, co-operative stores, recreation and education centres should be provided by the employer or Government near factory sites, if these are located away from the towns or cities.

These amenities will keep the worker healthy, build good habits and they, therefore, will take much interest in work.

Major public and private concerns have provided welfare and recreational centres. They have provided subsidised and good canteens, free education for workers' children, dispensaries and other facilities.

(*x*) *Business and Commercial Facilities.* Availability of the financial and banking facilities is an important consideration for the factories, which require constant feeding of the working capital. This is also necessary for the employees.

(*xi*) *Existence of Related Industries.* Specially, in the case of small scale industries, repairing is a problem. If such facilities are available in the existing area, repairs can be carried out immediately without affecting the production.

(*xii*) *Other Factors.* The factors like local bye-laws, incentives offerred by the Government, taxes, fire protection facilities, post and telegraph facilities should also be considered.

Based on the above considerations, one can easily note the clustering of jute industry in West Bengal, textile industry in Mumbai and Ahmedabad. Steel plants located along the Bihar, West Bengal, Orrisa belt as in steel plants' raw materials like coal, lime stone and iron ore are economical to transport. Similarly, cement plants are located near the lime stone and coal deposits. Fertiliser industries are based on gas, oil or naphtha and coal, and accordingly they are based near the source of raw materials.

Nowadays, the Government is trying to bring about a regional balance in industrial locations as reflected in the *Industrial Policy* resolution. Therefore where possible the industries are being installed in other areas also, sometimes in such areas various concessions are offerred by the Government.

1.2.2. Selection of a Particular Site

After selecting a general area for the plant, next step is to select a suitable site in that area. This is most important decision. Sometimes, all the requirements and features of suitable site may not be available at one particular location, in such cases it will be advantageous to find out a suitable site with a combination of maximum essential requirements of the particular industry from maximum overall economy point of view.

Important points which should be considered while selecting a specific site are discussed hereunder :

1. Community Attitude. Most communities usually welcome setting up of a new industry as it would provide direct and indirect employment opportunities to the local people. However, in case of polluting or adversely affecting industries, the local population provide resistance and tries its best that such industries stay as far away as possible. This resistance sometimes create law and order situation. Thus the attitude of the people and that of state Government influences the location of the industry.

2. Community Facilities. These are the facilities which affect the quality of life such as schools, hospitals, housing, banking, communication, police, fire protection, cultural, social, recreational, and other facilities.

3. Topography. This includes subsoil conditions suitable for taking bearing loads of the building foundation. The cost of levelling and developing the area, laying the water supply lines, electricity, drainage and sewage should remain within reasonable limits.

4. Transportation Facilities. The plant site should be accessible by road and rail, so that the transportation cost is minimum and movement is easy and quick.

5. Waste Disposal. The process waste including solid, liquid and gaseous effluents are required to be disposed off. The plant should be positioned so that prevailing winds carry out fumes away from populated areas, and that waste may be disposed off properly and at reasonable expenses.

6. Ecology and Pollution. Because of growing awareness towards maintenance of natural ecological balance, this aspect is gaining importance. Before selection of final area, it should be checked, if there is any restriction imposed in the area.

7. Size of Land. The plot of land must be sufficient in size to meet the needs of the proposed plant including parking areas and other facilities, and also space for future expansion. It should also be ensured that available land is free from any dispute.

8. Supporting Industires. The supporting industries and other services should be available in the nearby area.

1.2.3. Categories of Factors Affecting Plant Location

Various factors discussed above can be classified into following categories :

1. Critical Factors : These are the factors, which necessitates the location of plant in a particular area only making other factors

unimportant. For example, energy oriented plants would consider sites only where low-cost and plenty of electrical energy is available. Similarly, water oriented enterprise have to be installed where plenty of water is available.

2. Objective Factors : These are the factors which can be evaluated in money terms. Such factors are, labour cost, raw materials, utilities, taxes, cost of land, construction cost etc. Here it is necessary to mention that while labour cost is an objective factor, availability of sufficient labour of required type is a critical factor.

3. Subjective Factors : These are the factors which can be measured qualitatively. For example, nature of community support available.

1.3. SURVEY FOR ESTABLISHING AN ENTERPRISE

Before starting a new unit, a thorough survey should be undertaken to ascertain, whether the venture can give sufficient profit to justify the expenditure of time and investment. Procedure for the survey and starting a business unit is as under :

1. Analyse the product and survey the market.
2. Make an economic survey.
3. Determine the major objectives.
4. Design the product.
5. Determine the volume of production and size of plant.
6. Select the location.
7. Decide whether to buy or make parts.
8. Develop and select the manufacturing process and equipment.
9. Develop a plant layout and select a type of building.
10. Determine the capital requirements, financial plan, and profitability.
11. Develop an organisational structure and select personnel.
12. Launch the enterprise.

Above mentioned is a detailed list, however, it may be modified as per requirement. For example, for a service industry, there is no need for steps 4 and 7. Similarly for a new branch of a plant of an established product some of the steps will not be needed, as in those cases data must have been previously gathered.

During initiation and operation of an enterprise there are several chances of risks. Heavy losses and failures occur because of an

incomplete survey, poor planning and mismanagement. Application of the following methods will **avoid or minimise risks and losses.**

1. Thorough Survey. Thorough survey through qualified counsel and high caliber executives should be carried out so as to minimise the chances of losses and danger of failure.

2. Minimum Investment. A business may initially be started with minimum investment by subcontracting much of the production, hiring a building, buying power, and distributing the product through a sales agency. Once success is certain, management can directly proceed further by constructing a building, buying more equipment, generate own power if found economical, and participating directly in the distribution of the product.

3. Maximum Flexibility. Management should emphasize maximum flexibility in production facilities and distribution methods consistent with low cost operations. Emphasis should also be placed on the adaptability of the firm to changing economic conditions and to keep abreast technological advancement and avoiding obsolescence. In this connection a sound equipment replacement programme should be developed.

4. Risk Survey. A risk survey should be made about various aspects of the business in order to discover where losses may occur and what preventive action can be taken.

5. Safety Programme. A safety programme be developed so that it can prevent or reduce the hazards to the health and safety of employees and to physical property.

6. Insurance. This is final recourse for the rescue of risk which remains without possibility of elimination. Insurance is available, for almost all types of risks such as fire, windstorm, explosion, theft, flood, etc.

1.4. PHYSICAL FACILITIES LAYOUT

In industrial plants, emphasis is placed on plant layout, materials handling, and building design. Objective of making managerial decisions in respect of physical plant facilities is to achieve an integrated combination of operators, machines and equipment.

Plant layout is fundamentally a technique for achieving an economical arrangement of equipment and manufacturing process in conjunction with plant services. Its objective is to combine labour with the physical properties of plant (which includes machinery, plant services, and handling equipment) in such a manner that the

greatest output of high quality goods and services, manufactured at the lowest unit cost of production and distribution will result.

Principles of good organisation of physical facilities are applicable to service industries such as banks, hotels, hospitals, airports, rail road yards, harbours, depots and warehouses. The approach to and procedure for the layout of facilities for these diverse activities are substantially the same.

Layout design of physical facilities have been discussed in detail in the chapter on "Procedure for Plant Layout".

1.5. SELECTION OF SITE IN AN URBAN AREA

Advantages

1. It is sometimes possible to find an existing building which can be used to house the factory.
2. It is easier to sell the building, if it is desired, at a later stage.
3. Power and water is easily available.
4. If other factories are also situated in a big city, there will be good opportunity for discussing and having exchange of knowledge.
5. Good market for small manufacturers.
6. It is well served by railways and roads from various parts of the country so that transportation of incoming and outgoing materials is convenient and cheap.
7. It is a good labour market, where all types of labour is available. Seasonal labour is also easily obtained than that in a smaller centre of population, specially when unskilled labour is required.
8. Services for repairs and maintenance etc. can be available with existing industries.
9. Large number of Government facilities like Post office, Banks, Railways, Police and Fire protection will be easily available.
10. Houses for workers are easily available.
11. Education for the children of the employees is not a problem.

Disadvantages

1. Often sites are limited as sufficient land is not available and being congested climate will not be healthy.

2. The cost of land is high and rates are liable to increase further. Land for expansion is not available at reasonable rates. The larger the city, the higher the land rate.
3. Because of high standard of living, higher wages of labour will have to be paid.
4. More problems about labour and employer relations.
5. Cost of building will be high.
6. High taxes.

1.6. SELECTION OF SITE IN A RURAL AREA

Advantages

1. The cost of land is less than in a city area and usually easier to get space for future expansion.
2. The cheap land enables a more efficient layout of works to be made and gives greater freedom in selecting the most economic design for the buildings.
3. Rail and road connections can be arranged easily.
4. Labour supply may be arranged from the near by areas or by transport from where the labour is cheaply available.
5. Healthy surrounding and pleasant atmosphere.
6. Less labour trouble.
7. Lesser taxes and restrictions.

Disadvantages

1. Sufficient power and water facilities may not be available.
2. Repairing work may become difficult, because of less industries in the area.
3. Skilled workers are not easily available.
4. No recreational facilities.
5. Facilities for education to children and adults (part time courses) may not be available.
6. Government facilities may not be sufficient.
7. Transport and housing facilities may not be satisfactory.

1.7. PROCEDURE FOR SELECTING A SITE

For selecting a site following procedure should be followed :

1. Constitution of Site Selection Committee : This committee should be composed of people having knowledge and experience in the relevant fields.

2. Determining Company Needs. Needs are determined by establishing the goals, objectives and criteria including size of building and size of plot required.

3. Deciding Criteria for Selection. For the purpose of deciding criteria for selecting the region and actual site either a check list or a questionnaire is prepared.

4. Accumulate the Data. Necessary data or informations which may influence site selection are collected. This involves first the locating of sources of data, then the actual collection and finally tabulating or arranging them in formats.

5. Analyse the Data. After collecting, all the facts, figures and informations are then analysed. A base map pinpointing all suitable sites and such major features as : industrial, zoning boundaries, road, rail, air and water transportation network and major utility lines–water, sewage disposal, gas and power, is prepared.

6. Evaluate the Alternatives. Evaluation process requires the quantification of as many tangible factors as possible, with a judgment evaluation process applied to the intangible factors. The most common method of comparing the factors is by giving them a value or weight. Evaluation is done in following steps :

(*a*) Select the important factors for the enterprise,

(*b*) Rank them in order of importance, and

(*c*) Evaluate each region or site for each alternative location.

Each site is then depicted on a separate map, showing (*i*) road, rail, air and water transportation, and major utility lines of water, sewage disposal, gas and power, (*ii*) topographic features (*iii*) prevailing mind directions, (*iv*) adjacent land use and other data helpful in site selection.

7. Reduce Number of Alternatives. The number of alternatives are then reduced to about 6 for detailed analysis.

8. Investigation in Detail. Each of the potential site should then be visited by selection committee along with such other personnel as deemed advisable. This includes inviting consultants, architects, builders etc.

9. Collect and Analyse Further Data. In the final stage of selection sometimes it is found necessary to obtain additional information and data. After obtaining such data, committee then take a final view.

1.8. LOCATIONAL ECONOMICS

The selection of location for an industrial plant is a long time commitment. A new enterprise may suffer throughout its life due to unfavourable location. Once a plant has been built, the expense and disruption of activities necessary to move it to a more favorable location is quite impracticable. Therefore, the search for plant site justifies very careful consideration.

For evaluation of economical location following factors should be considered :

1. Raw material procurement. 2. Proximity to market.
3. Availability of labour, their training and compensation.
4. Availability of power. 5. Availability of finance.
6. Miscellaneous consideration like donations, subsidies, taxes and non-interference by government or local bodies, war and political effects and other facilities or bottlenecks.

The principle of Industrial Plant Location is that the sum of manufacturing and distributing cost should be at minimum for the best location.

Six important points are given above for economical location of a plant. The first two factors are related with the transportation cost. One should be clear that a plant may be located near the market as well as near the raw material site. But in actual practice, many times, due to some other factors, it is not possible to locate an industry near the market as well as raw material.

For economical analysis following factors play an important part.

1. *Factors for locating an undertaking near the raw material site :*
   - (*a*) When source of raw materials is the controlling factor?
   - (*b*) When materials are bulky and of relatively low price?
   - (*c*) When materials are small and of high unit price?
   - (*d*) When raw materials are greatly reduced in bulk during the process of manufacture?
   - (*e*) When raw materials are perishable and process makes them less perishable?

The examples are: processing industries, cement, paper, meat, canning (fruit) etc.

2. *Factors responsible for locating an industry near the market:*
   (*a*) When the size or bulk of the product is more?
   (*b*) Render it more fragile.
   (*c*) More susception about the spoilage.

Examples are : shoes, furniture, glassware industries.

3. *The factors responsible for the economy of labour :*
   (*a*) The ratio of labour cost to total manufacturing cost. If the ratio is small then this factor is not important.
   (*b*) The possibility of reduction in labour cost by using better methods or better quality of labour.
   (*c*) The type of labour required.

For example, the textile industries, silk and carpet making industries, sports goods etc.

4. *Economy and availability of power:* This point is similar to the raw material procurement. If power is generated from coal, then coal is a raw material. Hence steel plants are located near the coal-mines etc.
5. Other major factor that influences the location is availability of finance. Finance can be obtained from Government agencies, banks etc. under special schemes for specified regions/areas.
6. *Miscellaneous considerations:* The following factors also influence the layout :
   (*a*) An offer for a factory site or an existing plant.
   (*b*) A rebate of taxes and period for which it will remain available.
   (*c*) Non-interference by local or Government bodies.
   (*d*) The location should not be near the border of the country to safeguard from risk of war.
   (*e*) For smooth going, political interference should not be there.

For comparing, the problem is divided into five main factors. The cost of each factor or sub-factor is calculated per unit as shown in Table 1.1, which will help us in deciding most economical site.

It is not necessary to consider all the factors of site selection given in Table 1.1, only the most effective factors are considered. An optimal location is one, which is the best in given and existing circumstances.

Table 1.1 Chart : Determination of Lower Cost Site

Particulars	*Charge per unit at site*			
	A	*B*	*C*	*D*
Raw Materials (*a*) ..... (*b*) ..... (*c*) ..... (*d*) .....etc.				
Fuel and Power (*a*) Electric (*b*) Coal (*c*) Water (*d*) Gas etc.				
Factory Expenses (*a*) Labour (*b*) Supervision (*c*) Inspection (*d*) Testing etc.				
General Expenses (*a*) Administration (*b*) Salaries (*c*) Taxes (*d*) Insurance (*e*) Postage etc.				
Distribution Expenses (*a*) Advertising (*b*) Packing (*c*) Stocking (*d*) Transport (*e*) Sales etc.				
Total cost/unit				

Example 1.1. *A comparison for three cities is given below on the basis of factors which effects the locational economics :*

Factors (per month)	*A* *Rs.*	*B* *Rs.*	*C* *Rs.*
Rent	20,000	10,000	10,000
Labour	135,000	130,000	160,000
Freight charges	81,000	64,000	28,000
Taxes	0	3,500	2,000
Power	6,000	6,000	6,000
Total operating cost	242,000	213,500	206,000
Community attitude Employee housing	Indifferent excellent	wants business adequate	indifferent poor

Now on the basis of operating costs alone *C* city would appear to be best location. If we include the other factors such as community attitude and employee housing, *B* offers the best possibilities for location and would probably be chosen.

Example 1.2. *A new industrialist wants to locate a small factory. On surveying he found the three possibilities of Delhi, Ghaziabad and Meerut with different advantages. The initial investment is going to be of the order of Rs. 2 crores. The industrialist wants to calculate the rate of return of the three proposed sites, the site with highest rate of return will be the optimal choice of location for the factory.*

Rs. in Lacs.

Factors	*Delhi*	*Ghaziabad*	*Meerut*
1. Expected sales during the first year (*A*)	250	250	250
2. Distribution charges during the year (*B*)	40	42	47
Thus net sales $C = A - B$	210	208	203
3. Raw material and other materials	90	80	70
4. Transportation of (3)	20	25	35
5. Labour wages and salaries	25	30	25
6. Fuel and power etc.	20	30	30
7. Miscellaneous	15	15	20
Total of 3 to 7 = (*D*)	170	180	180

Out of the above factors 1 and 2 can be classified under sales and distribution cost and other five factors under production cost.

Net profit $C - D = E$	40	28	23
Rate of return = $\frac{E \times 100}{\text{initial investment}}$	20%	14%	11.5%

Thus location of the factory at Delhi with 20% rate of return is the optimal choice for the factory as it gives maximum rate of return. The rate of return for Ghaziabad and Meerut are 14% and 11.5% respectively. However from analysis for the cost of raw material and other materials, Delhi is costlier with Rs. 90 lacs in comparison with Rs. 80 lacs and Rs.70 lacs respectively at Ghaziabad and Meerut. The rate of return is highest at Delhi due to the following reasons :

1. Lower distribution costs
2. Lower transportation costs for raw material and others
3. Lower fuel and power supply cost.

Although analysis such as given in above example does not make the final location decision. Management may find it quite useful in collecting the facts on which a sound economic choice is based.

1.8.1. Market Survey

A market analysis of the area is conducted to answer the following questions :

1. If there is a market which could be served, if retail price of product is reduced.
2. Whether quick delivery of the product can be made to the particular market by better plant location.
3. Whether there are competitors for the product in the market. Whether demand for product may increase. Whether an additional plant is required to meet the future demand.
4. What is the potential purchasing power of the market ?
5. What are the buying habits of local people, and what must be done to fit your service to these habits ?

Economic Factors

Locational economics for an enterprise includes a consideration of the product to be manufactured, the processes and machinery to be used, and the service and facilities required. To know this, following factors may be studied :

1. *Product*
   (*a*) Nature, (*b*) Volume, and (*c*) Value.
2. *Production process*
   (*a*) Continuous, (*b*) Intermittent, and (*c*) Interrupted.
3. Manufacturing machinery.
4. Other manufacturing equipment.
5. Special manufacturing requirements.
6. Service.
   (*a*) Steam, (*b*) Gas, (*c*) Water, (*d*) Air or high pressure,
   (*e*) Electricity, and (*f*) Sewerage.

In most plant location models, the objective is to minimise the sum of all costs affected by location. Some items of cost may be higher at location A but others may be higher at location B. Our aim is to seek the location that minimises the total cost. In attempting to minimise costs, we should consider not only today's costs but also long run cost as well. Therefore, we must be interested in predicting the influence of some of the intangible factors that may affect future costs. This is an example of a managerial decision with multiple criteria, where trade-offs must be made between the various values and criteria.

For example, there are m users whose locations and demands are known. These demands must be met from a set of facilities that can be located at any of the n identified sites. The objective is to minimise the total cost of production and distribution, and the fixed cost to install the facilities. This layout problem requires answers to following questions :

(*a*) How many facilities are required ?

(*b*) Where should each facility be located ?

(c) What should be allocation for the demand of a user to various facilities ?

If there is only one facility to be located, the total cost be evaluated for each of n possible locations. Let us assume,

F_j = Fixed installation costs for locating a facility of site j.

Cij = Cost per unit to serve user i from the facility at j.

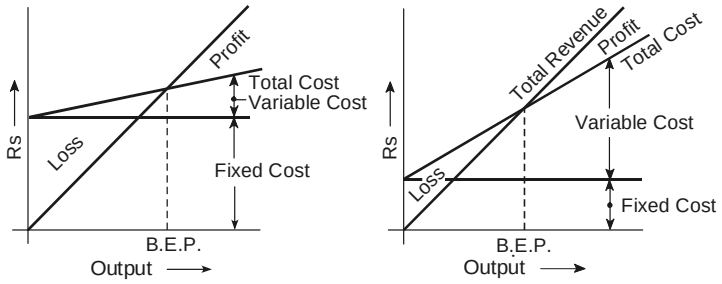
Di = Demand for user i.

$$\therefore \text{Total cost} = Fj + \sum_{i=1}^{n} C_{ij} D_i$$

In the above equation, first component represents the fixed costs (land, building, etc.) for installing the facility, and the second component represents the total cost of production and distribution to meet the demand. If the production cost per unit is identical at all locations, then C_{ij} will reflect only the transportation cost per unit for shipments from site j to user i.

As we have seen revenues and costs are both affected by facility location. Break-even analysis helps relate costs and revenues to facility location. A break-even analysis is a graphical and algebraic representation of the relationships among volume of output, costs and revenues. Costs can generally be divided into fixed and variable costs. Fixed costs include heating, lighting, and administrative expenses that are the same irrespective of volume of output. Variable costs are those that fluctuate directly with volume of output. Generally, variable costs are the costs of direct labour and material.

Fig. 1.1 shows the total revenue and total costs. Costs exceed revenues in the initial stages of output upto a point, known as break-even point (BEP), the level of volume for which total costs equal total revenues. Thereafter, revenues exceed costs of operation.



Location A : High fixed costs and low variable costs.

Location B : HIgh variable costs and low fixed costs.

Fig. 1.1. Break-even points for two contrasting locations.

Break-even analysis identifies the level of output that must be reached in order to recover all the costs of operation through revenues.

Reasons for Locational Changes

Reasons for changing locations are :

1. Need for greater capacity.
2. *Changes in resources*. The cost of availability of labour, raw materials etc. may change.

3. The geography of demand may shift.
4. Companies may merge, making facilities redundant.
5. New products may be introduced.
6. Change in political and economic conditions.

1.9. TECHNIQUES USED FOR SELECTING BEST PLANT LOCATION

Following are the few important techniques used to decide best location from the available alternative locations :

1. Subjective Techniques

(*a*) *Industry precedence :* This occurs when a new facility is located in an area previously selected by similar industry. This is based on the assumption that, "if the location was best for similar firms in the past it must be best for us now".

(*b*) *Preferential factor :* This usually involves a personal whim or preferences. This is not a professional approach and is not a good business decision-making process.

(*c*) *Dominant factor :* This occurs when one factor dominates any other factors and could influence the location decision *e.g.* mining or petroleum drilling operations must be located in the areas where the mineral resource is available.

2. Qualitative Techniques.

This technique is also known as "factor ranking" system. Ranking may be conducted on an overall location or individual factor basis. In both these cases, no comparative relationship for values within the factor other than position in the list is established. A location is either better than or worse than another for the particular factor. Ranking is therefore unsatisfactory.

3. Semi-quantitative Techniques.

This technique is also known as "factor weight-rating" system. In this, rating scales are used to compare regions, communities or sites against each other. The rating techniques are used to substitute a point value when monetary values are unobtainable. In this system, variable weights are assigned to each of the factors and each location is evaluated along the factor scale.

4. Quantitative Techniques.

Following are the important quantitative techniques used for selecting a best location :

(*i*) Break-even analysis, (*ii*) Economic/cost analysis.

(*iii*) Transportation model.

5. Weight-Rating Method.

Table 1.2, illustrates the weighing method for selection of local site and other influencing factors. While weighing, we establish a percentage to represent the relative importance. It is important that the better the technique for getting the weighing, the better the decision. In this a questionnaire survey or group discussion may help a lot.

Before making a good decision, we should have a clear idea of objective. We should know what is the real problem, and what are the different alternatives possible for the solution. Further it is quite easy to get decision by putting numerical values, for the factors which cannot be ordinarily evaluated objectively.

Step 1. *Find the important factors.* First of all find the factors which are considered important. For finding this, statistical analysis, questionnaire survey or other techniques may be employed. In order to select the plant site, we have grouped some of the factors in the order of importance as shown in Table 1.2.

Table 1.2.

Factors	*Relative weighing*	*Other influencing factors*
1. Labour	40	Skilled or unskilled supply, wages, strike
2. Supplies of raw materials	20	Source and cost for raw material and other supplies likewise refractories, machine parts, charcoal, lubricating oil etc.
3. (*a*) Power	5	Govt. agency or private, cost, service
(*b*) Fuel	4 (10)	Cost and quality, oil, gas, coal, coke.
(*c*) Water supply,	1	Quality and cost.
4. Transportation	10	Transportation of product and raw material by road, rail or water.
5. Taxes and Law	10	Government and local.
6. (*a*) Climate	2 (5)	Maximum and minimum temperature average rainfall or snowfall
(*b*) Living condition	3	Cost of living, sanitation and health, housing facilities.
7. Other facilities like		
(*a*) Construction cost	3 (5)	Provision for expansion, material and labour supply.
(*b*) Selection of site,	2	Railway connection, property of soil, drainage, availability of labour.
Total	100	

Step 2. *Putting the numerical values for each factor, for each alternative.* This can be done at best when all the factors are considered according to the same scale of desirability. In our example we use numbers upto 10, where 10 is for the perfect desirability. Each factor should be considered separately. There may be many methods to get these evaluations like cost studies, statistical analysis, work samplings questionnaires and the other tools of Operation Research and Industrial Engineering.

Step 3. *Weighing the factors with relative economic importance.* In this we establish a percentage (out of 100) to represent the relative importance. In our example we weighed the factors putting them in the middle column as shown in Table 1.3. It may be important that the better the technique for getting the weighing, the better the decision. In this a questionnaire survey or group discussion may help a lot.

Step 4. *Calculating weighed source for alternatives.* For this, multiply each unweighed point rating with the appropriate weighed percentage. In our example for factor 1, *i.e.* availability of labour for site 1, multiplying 10 by 40. Now complete the table as per Table 1.3. Finally add the weighed points to find the best site to choose.

Table 1.3.

Important factors	*Unweighed site evaluation*			*Weighing %*	*Weighted site evaluation*		
	Site I	*Site II*	*Site III*		*Site I*	*Site II*	*Site III*
1. Availability of labour	10	8	7	40	400	320	280
2. Availability of raw materials	8	7	6	20	160	140	120
3. Availability of power etc.	8	7	10	10	80	70	100
4. Availability of transport	7	9	8	10	70	90	80
5. Local taxes and other cost	6	10	9	10	60	100	90
6. Climatic condition	5	9	10	5	25	45	50
7. Other facilities	6	5	10	5	30	25	50
Total evaluation score	50	55	60	100	825	790	770
Relative site desirability	3rd	2nd	1st		1st	2nd	3rd

Now observe that how the choice is reversed by weighing. As Site I with 825 points becomes the first choice instead of the third.

LOCATION OF FACILITIES

Example 1.3. *A company planning to manufacture a product has to decide one location out of Mysore, Bangluru and Hyderabad. Fixed costs at these three locations are estimated to be Rs. 30 lacs, 50 lacs and 25 lacs per annum respectively. The variable costs are Rs. 300, 200 and 350 per unit respectively. Expected sales price of the product is Rs. 700 per unit. Find out :*

(*a*) *range of annual production for which each location is most economical, and*

(*b*) *which one of three locations is best at a production of 18000 units ?*

Solution : The total costs at the 3 locations are :

1. At Mysore : Total cost = 30,00,000 + 300x
2. At Bangluru : Total cost = 50,00,000 + 200x.
3. At Hyderabad : Total cost = 25,00,000 + 350x.

To find out economical location, we now compute and plot the total costs per annum at these locations for production volumes of 5000, 10,000, 15,000, 20,000 and 25,000 units?

1. **At Mysore**

Volume	5000	10000	15000	20000	25000
	=30,00,000 + 300(5000)	30,00,000+ 300(10000)	30,00,000+ 300(15000)	30,00,000+ 300(20000)	30,00,000+ 300(25000)
Total cost in Rs.,	=45 lacs	=60 lacs	=75 lacs	=90 lacs	=105 lacs

2. **At Bangalore**

Volume	5000	10000	15000	20000	25000
	=50,00,000+ 200(5000)	50,00,000+ 200(10000)	50,00,000+ 200(15000)	50,00,000+ 200(20000)	50,00,000+ 200(25000)
Total cost in Rs.	=60 lacs	=70 lacs	=80 lacs	=90 lacs	100 lacs

3. **At Hyderabad**

Volume	5000	10000	15000	20000	25000
	=25,00,000+ 350(5000)	25,00,000+ 350(10000)	25,00,000+ 350(15000)	25,00,000+ 350(20000)	25,00,000+ 350(25000)
Total cost in Rs.	=42.5 lacs	=60 lacs	=77.5 lacs	=95 lacs	112.5 lacs

The total cost for all these production volumes for these three locations are plotted as shown in the Fig. 1.2.

From the Fig. 1.2 it is clear that at production volume (*a*) upto 10,000 units Hyderabad, (*b*) between 10,000 to 20,000 units Mysore, and (*c*) above 20,000 units Bangaluru are the most economical locations for the plant.

For 18000 units of production volume per year, Mysore is the most economical location.

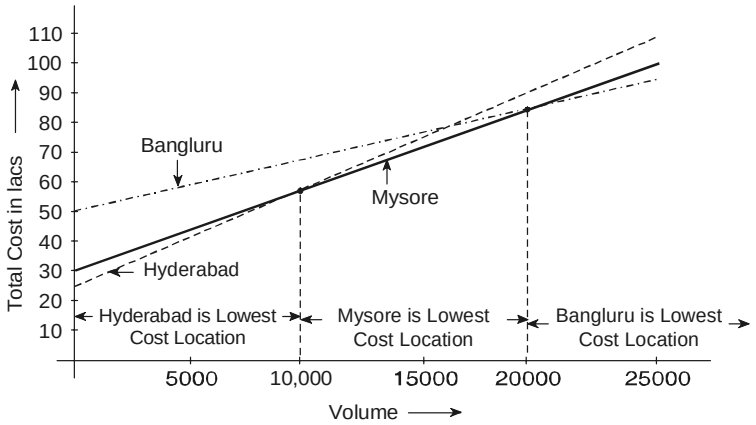


Fig. 1.2. Production volume v/s cost for various locations.

LAYOUT OF FACILITIES

Example 1.4. *Management of an industry is considering an interchange of departments 3 and 6 in the existing layout. Existing layout is as below :*

1	3	5
2	4	6

Weekly frequencies of interdepartmental materials handling are as under :

From \ To	1	2	3	4	5	6
1		0	90	160	50	0
2			70	0	100	130
3				20	0	0
4					180	10
5						40
6						

What is the effect of interchange of the departments 3 and 6 in the layout ? Assume, (i) per unit length interdepartmental costs of material handling are equal, (ii) All the departments are of the same size and configuration.

Solution.

(*i*) The distance matrix of the existing layout can be drawn as under :

From \ To	1	2	3	4	5	6
1		1	1	2	2	3
2			2	1	3	2
3				1	1	2
4					2	1
5						1
6						

Total cost matrix of the existing layout is calculated as under by combining the interdepartmental materials handling frequencies and the distance matrix :

From \ To	1	2	3	4	5	6	Total
1		0	90	320	100	0	510
2			140	0	300	260	700
3				20	0	0	20
4					360	10	370
5						40	40
6							
						Total	1640

(*ii*) By interchanging the 3 and 6 departments, the layout would become as under :

1	6	5
2	4	3

Distance matrix for modified layout can be drawn as under :

From \ To	1	2	3	4	5	6
1		1	3	2	2	1
2			2	1	3	2
3				1	1	2
4					2	1
5						1
6						0

Distance matrix and interdepartment materials handling frequencies are combined as under to form total cost matrix :

From \ To	1	2	3	4	5	6	Total
1		0	270	320	100	0	690
2			140	0	300	260	700
3				20	0	0	20
4					360	10	370
5						40	40
6							
						Total	1820

Thus, interchange of departments 3 and 6 increases total materials handling cost, and is not a desirable modification, unless there are other more pressing reasons.

1.10. SPECIFIC LOCATION DECISION—ECONOMIC ASPECTS

Since this decision is most important and if once taken, not easy to modify or reverse, as these involve long term commitment of the firm. While deciding about location of the factory, the firm has to take into consideration the various advantages and drawbacks arising from the distances of the input and commodity markets from the proposed locations of output. The final decision would emerge out of the comparative evaluation of the different input locations and markets for output.

A firm would like to locate the factory in a place where the availability of inputs is cheap and reliable. The inputs may be land, labour, raw material, energy, transportation and water supply. Heavy, voluminous, fragile and perishable inputs are difficult and expensive to transport. A firm which uses such inputs, would benefit by locating its factory near the place of origin of these inputs. For example, considering the volume of coal and the bulk need of the steel mills for coal, steel mills are located in the vicinity of coal fields—sugar, paper, food preservation, and brick industries are some of those industries which are situated generally near the source of their raw material.

Firms producing goods that are bulky, fragile, perishable or otherwise costly to transport, like to locate their factories near the place of output market. In service industries involving high technology, personal contact of producers with the customers is important, which

attract firms in close proximity to the market. Ancillary industries are also located near the parent company which is the main market for the former. Furniture factories, bakeries (perishable goods) and soft drinks are the examples of this category, which are located close to the output market.

Mathematical model for making a decision for factory location can be made as under, within the frame work of profit maximisation. Let a firm use n inputs $(I_1, I_2 \ldots\ldots I_n)$ and sell in m markets $(X_1, X_2 \ldots\ldots X_m)$. With respect to each location the firm has respective cost (C_i) and revenue (R_i). Let per unit cost of input i at location l be C_i^l and price per unit of output j at location l be P_i^j. The maximum profit location (n_i) for the factory can be selected with the help of following model :

Cost at location l	:	$C_i = \Sigma\, C_i^l \,.\, I_i^l$
Revenue at location l	:	$R_i = \Sigma\, P_i^l\, X_i^l$
Production function	:	$X = f(I_1, I_2 \ldots\ldots I_n)$
Production mix	:	$X = \Sigma X_i$
Objective function mix	:	$\pi_i = R_i - C_i$

1.10.1. Cost Economics

The site which gives the minimum total cost per unit, in absence of any other critical consideration should be selected as a suitable plant location. Therefore, main consideration is to minimise total cost which consists of :

1. Capital cost which includes cost of land, land development, building and services, environmental protection measures and infrastructural facilities.

2. Operating cost which includes cost of capital, overhead and depreciation on capital, cost of material, labour and other variable costs.

3. Distribution cost which includes transportation and sales cost.

Interrelationship between these costs and plant capacities are shown in Fig. 1.3. Profitable operation takes place above break-even point (BEP). After certain value the rise of distribution cost more than offsets the fall of operating cost resulting in a rise in the total cost which might become higher then revenue at break-down point (BDP). This shows the plant has reached beyond economies of scale, indicating the necessity for additional plants.

For a **Multiple Plant Location**, relations between the total cost (Fixed+Variable costs) and volume of production are shown in

Fig. 1.4 for various locations to enable management to carry out a break-even point analysis or to decide optimum capacity at such locations. One BEP is identified for each location.

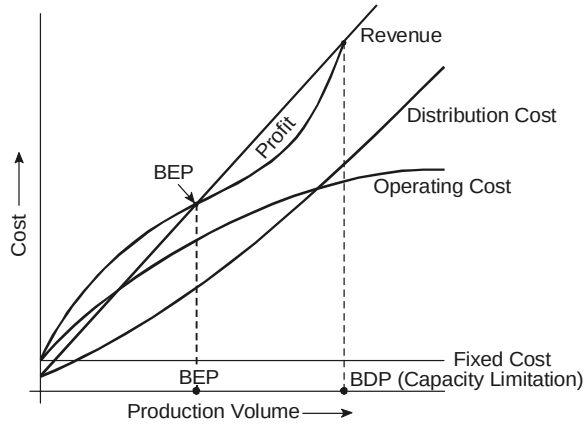


Fig. 1.3. Economics of scale for single plant location.

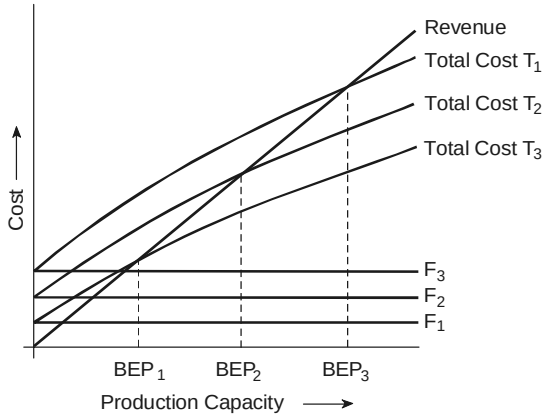


Fig. 1.4. Cost economics for multiple location.

REVIEW QUESTIONS

1. What are the factors that are considered for selecting a site for a factory ?
2. You are proposed to establish a sugar mill in Rajasthan, discuss the factors which should be considered in selecting a site.
3. Discuss how site of a factory would influence the production cost?

4. Give the comparative advantages and disadvantages of big city and small city in plant location.
5. For what type of factory, single storey building is preferred to the multi-storey building ? Discuss.
6. Discuss the merits and demerits of a single-storey and multi-storey industrial building. Describe the procedure necessary to be adopted for the physical location of the plants and equipments.
7. Name and discuss the factors which you need for the selection of a plant site. What are the advantages and disadvantages of town and country situation ?
8. Discuss primary factors to be considered in selecting the site of a factory.
9. What factors should be considered before the layout of a factory is made ?
10. Suggest some plants and show how the factory can be expanded in future ?
11. What factors would you consider in choosing between extension of factory or working another shift when increased production becomes necessary ?
12. Discuss the factors that influence the location of plant with particular reference to Mathura Petroleum Refinery. Do you justify such a decision?
13. It is generally felt that 'rural areas are good for locating large plant, semi-urban areas for locating medium-sized plants, and urban areas for small scale plants'. Comment.
14. What are the steps of a facility location study ? In case you want to locate a soft drink bottling plant, what factors would you consider for taking a location decision ? How would you go about conducting location study ?
15. Why is the location of a plant of great concern to the management ?
16. What do you understand by facilities ? What are the guidelines in locating a facility ?
17. What factors should be considered in facility location ?
18. In studying individual sites, what particular details, technical and legal factors, should be considered ?
19. Write short notes on :
    (*a*) Locational economics. (*b*) Location of small plants.
20. Explain the weighing method of plant location.