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PLANT LOCATION AND LAYOUT

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2.1 INTRODUCTION AND MEANING

Plant location or the facilities location problem is an important strategic level decision-making for an organisation. 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.

2.2 NEED FOR SELECTING A SUITABLE LOCATION

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

- I. When starting a new organisation, *i.e.*, location choice for the first time.
- II. In case of existing organisation.
- III. In case of Global Location.

I. In Case of Location Choice for the First Time or New Organisations

Cost economies are always important while selecting a location for the first time, but should keep in mind the cost of long-term business/organisational objectives. The following are the factors to be considered while selecting the location for the new organisations:

1. **Identification of region:** The organisational objectives along with the various long-term considerations about marketing, technology, internal organisational strengths and weaknesses, region-specific resources and business environment, legal-governmental environment, social environment and geographical environment suggest a suitable region for locating the operations facility.

2. **Choice of a site within a region:** Once the suitable region is identified, the next step is choosing the best site from an available set. Choice of a site is less dependent on the organisation's long-term strategies. Evaluation of alternative sites for their tangible and intangible costs will resolve facilities-location problem.

The problem of location of a site within the region can be approached with the following cost-oriented non-interactive model, *i.e.*, dimensional analysis.

3. **Dimensional analysis:** If all the costs were tangible and quantifiable, the comparison and selection of a site is easy. The location with the least cost is selected. In most of the cases intangible costs which are expressed in relative terms than in absolute terms. Their relative merits and demerits of sites can also be compared easily. Since both tangible and intangible costs need to be considered for a selection of a site, dimensional analysis is used.

Dimensional analysis consists in computing the relative merits (cost ratio) for each of the cost items for two alternative sites. For each of the ratios an appropriate weightage by means of power is given and multiplying these weighted ratios to come up with a comprehensive figure on the relative merit of two alternative sites, *i.e.*,

$C_1^M, C_2^M, \dots, C_z^M$ are the different costs associated with a site M on the 'z' different cost items.

$C_1^N, C_2^N, \dots, C_z^N$ are the different costs associated with a site N and $W_1, W_2, W_3, \dots, W_z$ are the weightage given to these cost items, then relative merit of the M and site N is given by:

$$\left(C_1^M / C_1^N\right)^{W_1} \times \left(C_2^M / C_2^N\right)^{W_2} \dots \left(C_z^M / C_z^N\right)^{W_z}$$

If this is > 1 , site N is superior and vice-versa.

When starting a new factory, plant location decisions are very important because they have direct bearing on factors like, financial, employment and distribution patterns. In the long run, relocation of plant may even benefit the organization. But, the relocation of the plant involves stoppage of production, and also cost for shifting the facilities to a new location. In addition to these things, it will introduce some inconvenience in the normal functioning of the business. Hence, at the time of starting any industry, one should generate several alternate sites for locating the plant. After a critical analysis, the best site is to be selected for commissioning the plant. Location of warehouses and other facilities are also having direct bearing on the operational performance of organizations.

The existing firms will seek new locations in order to expand the capacity or to place the existing facilities. When the demand for product increases, it will give rise to following decisions:

- Whether to expand the existing capacity and facilities.
- Whether to look for new locations for additional facilities.
- Whether to close down existing facilities to take advantage of some new locations.

II. In Case of Location Choice for Existing Organisation

In this case a manufacturing plant has to fit into a multi-plant operations strategy. That is, additional plant location in the same premises and elsewhere under following circumstances:

1. Plant manufacturing distinct products.
2. Manufacturing plant supplying to specific market area.
3. Plant divided on the basis of the process or stages in manufacturing.
4. Plants emphasizing flexibility.

The different operations strategies under the above circumstances could be:

1. **Plants manufacturing distinct products:** Each plant services the entire market area for the organization. This strategy is necessary where the needs of technological and resource inputs are specialized or distinctively different for the different product-lines.

For example, a high quality precision product-line should not be located along with other product-line requiring little emphasis on precision. It may not be proper to have too many contradictions such as sophisticated and old equipment, highly skilled and semi-skilled personnel, delicate processes and those that could permit rough handlings, all under one roof and one set of managers. Such a setting leads to much confusion regarding the required emphasis and the management policies.

Product specialization may be necessary in a highly competitive market. It may be necessary to exploit the special resources of a particular geographical area. The more decentralized these pairs are in terms of the management and in terms of their physical location, the better would be the planning and control and the utilization of the resources.

2. **Manufacturing plants supplying to a specific market area:** Here, each plant manufactures almost all of the company's products. This type of strategy is useful where market proximity consideration dominates the resources and technology considerations. This strategy requires great deal of coordination from the corporate office. An extreme example of this strategy is that of soft drinks bottling plants.

3. **Plants divided on the basis of the process or stages in manufacturing:** Each production process or stage of manufacturing may require distinctively different equipment capabilities, labour skills, technologies, and managerial policies and emphasis. Since the products of one plant feed into the other plant, this strategy requires much centralized coordination of the manufacturing activities from the corporate office that are expected to understand the various technological aspects of all the plants.

4. **Plants emphasizing flexibility:** This requires much coordination between plants to meet the changing needs and at the same time ensure efficient use of the facilities and resources. Frequent changes in the long-term strategy in order to improve be efficiently temporarily, are not healthy for the organization. In any facility location problem the central question is: 'Is this a location at which the company can remain competitive for a long time?'

For an established organization in order to add on to the capacity, following are the ways:

(a) *Expansion of the facilities at the existing site*: This is acceptable when it does not violate the basic business and managerial outlines, *i.e.*, philosophies, purposes, strategies and capabilities. For example, expansion should not compromise quality, delivery, or customer service.

(b) *Relocation of the facilities (closing down the existing ones)*: This is a drastic step which can be called as 'Uprooting and Transplanting'. Unless there are very compelling reasons, relocation is not done. The reasons will be either bringing radical changes in technology, resource availability or other destabilization.

All these factors are applicable to service organizations, whose objectives, priorities and strategies may differ from those of hardcore manufacturing organizations.

III. In Case of Global Location

Because of globalisation, multinational corporations are setting up their organizations in India and Indian companies are extending their operations in other countries. In case of global locations there is scope for virtual proximity and virtual factory.

VIRTUAL PROXIMITY

With the advance in telecommunications technology, a firm can be in virtual proximity to its customers. For a software services firm much of its logistics is through the information/communication pathway. Many firms use the communications highway for conducting a large portion of their business transactions. Logistics is certainly an important factor in deciding on a location—whether in the home country or abroad. Markets have to be reached. Customers have to be contacted. Hence, a market presence in the country of the customers is quite necessary.

VIRTUAL FACTORY

Many firms based in USA and UK in the service sector and in the manufacturing sector often out sources part of their business processes to foreign locations such as India. Thus, instead of one's own operations, a firm could use its business associates' operations facilities. The Indian BPO firm is a foreign-based company's 'virtual service factory'. So a location could be one's own or one's business associates. The location decision need not always necessarily pertain to own operations.

REASONS FOR A GLOBAL/FOREIGN LOCATION

A. Tangible Reasons

The tangible reasons for setting up an operations facility abroad could be as follows:

Reaching the customer: One obvious reason for locating a facility abroad is that of capturing a share of the market expanding worldwide. The phenomenal growth of the GDP of India is a big reason for the multinationals to have their operations facilities in our country. An important reason is that of providing service to the customer promptly and economically which is logistics-dependent. Therefore, cost and ease of logistics is a reason for setting up manufacturing facilities abroad. By logistics set of activities closes the gap between production of goods/services and reaching of these intended goods/services to the customer to his satisfaction. Reaching the customer is thus the main objective. The tangible and intangible gains and costs depend upon the company defining for itself as to what that 'reaching' means. The tangible costs could be the logistics related costs; the intangible costs may be the risk of operating in a foreign country. The

tangible gains are the immediate gains; the intangible gains are an outcome of what the company defines the concepts of reaching and customer for itself.

The other *tangible reasons* could be as follows:

- (a) The host country may offer substantial tax advantages compared to the home country.
- (b) The costs of manufacturing and running operations may be substantially less in that foreign country. This may be due to lower labour costs, lower raw material cost, better availability of the inputs like materials, energy, water, ores, metals, key personnel etc.
- (c) The company may overcome the tariff barriers by setting up a manufacturing plant in a foreign country rather than exporting the items to that country.

B. Intangible Reasons

The intangible reasons for considering setting up an operations facility abroad could be as follows:

1. Customer-related Reasons

- (a) With an operations facility in the foreign country, the firm's customers may feel secure that the firm is more accessible. Accessibility is an important 'service quality' determinant.
- (b) The firm may be able to give a personal touch.
- (c) The firm may interact more intimately with its customers and may thus understand their requirements better.
- (d) It may also discover other potential customers in the foreign location.

2. Organisational Learning-related Reasons

- (a) The firm can learn advanced technology. For example, it is possible that cutting-edge technologies can be learned by having operations in a technologically more advanced country. The firm can learn from advanced research laboratories/universities in that country. Such learning may help the entire product-line of the company.
- (b) The firm can learn from its customers abroad. A physical location there may be essential towards this goal.
- (c) It can also learn from its competitors operating in that country. For this reason, it may have to be physically present where the action is.
- (d) The firm may also learn from its suppliers abroad. If the firm has a manufacturing plant there, it will have intensive interaction with the suppliers in that country from whom there may be much to learn in terms of modern and appropriate technology, modern management methods, and new trends in business worldwide.

3. Other Strategic Reasons

- (a) The firm by being physically present in the host country may gain some 'local boy' kind of psychological advantage. The firm is no more a 'foreign' company just sending its products across international borders. This may help the firm in lobbying with the government of that country and with the business associations in that country.
- (b) The firm may avoid 'political risk' by having operations in multiple countries.
- (c) By being in the foreign country, the firm can build alternative sources of supply. The firm could, thus, reduce its supply risks.

- (d) The firm could hunt for human capital in different countries by having operations in those countries. Thus, the firm can gather the best of people from across the globe.
- (e) Foreign locations in addition to the domestic locations would lower the market risks for the firm. If one market goes slow the other may be doing well, thus lowering the overall risk.

2.3 FACTORS INFLUENCING PLANT LOCATION/FACILITY LOCATION

Facility location is the process of determining a geographic site for a firm's operations. Managers of both service and manufacturing organizations must weigh many factors when assessing the desirability of a particular site, including proximity to customers and suppliers, labour costs, and transportation costs.

Location conditions are complex and each comprises a different Characteristic of a tangible (i.e. Freight rates, production costs) and non-tangible (i.e. reliability, Frequency security, quality) nature.

Location conditions are hard to measure. Tangible cost based factors such as wages and products costs can be quantified precisely into what makes locations better to compare. On the other hand non-tangible features, which refer to such characteristics as reliability, availability and security, can only be measured along an ordinal or even nominal scale. Other non-tangible features like the percentage of employees that are unionized can be measured as well. To sum this up non-tangible features are very important for business location decisions.

It is appropriate to divide the factors, which influence the plant location or facility location on the basis of the nature of the organisation as

1. **General locational factors**, which include controllable and uncontrollable factors for all type of organisations.
2. **Specific locational factors** specifically required for manufacturing and service organisations.

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.

2.3.1 General Locational Factors

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

CONTROLLABLE FACTORS

1. Proximity to markets
2. Supply of materials
3. Transportation facilities
4. Infrastructure availability
5. Labour and wages

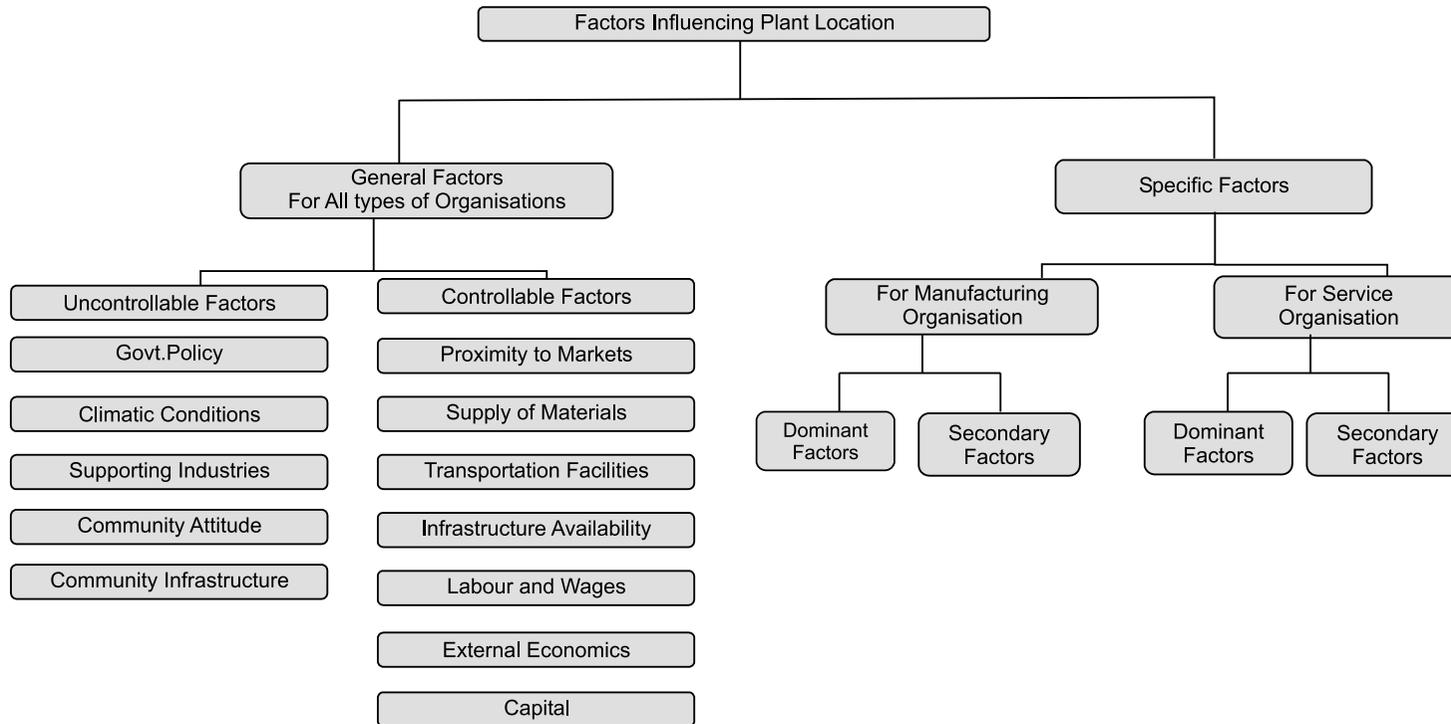


Fig. 2.1 *Factors influencing plant location.*

6. External economies
7. Capital

UNCONTROLLABLE FACTORS

8. Government policy
9. Climate conditions
10. Supporting industries and services
11. Community and labour attitudes
12. Community Infrastructure

CONTROLLABLE FACTORS

1. Proximity to markets: Every company is expected to serve its customers by providing goods and services at the time needed and at reasonable price organizations may choose to locate facilities close to the market or away from the market depending upon the product. When the buyers for the product are concentrated, 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 raw material: It is essential for the organization to get raw material in right qualities and time in order to have an uninterrupted production. This factor becomes very important if the materials are perishable and cost of transportation is very high.

General guidelines suggested by Yaseen regarding 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 losing raw material is demanded, 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., become the prominent factors in deciding the location. 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. The history of labour relations in a prospective community is to be studied. Prospective community is to be studied. Productivity of labour is also an important factor to be considered. Prevailing wage pattern, cost of living and industrial relation and bargaining power of the unions' forms in important considerations.

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. As large corporations have realized that inventories and warehouses have become a major cost factor, they have tried reducing inventory costs by launching "Just in Time" production system (the so called Kanban System). This high efficient production system was one main factor in the Japanese car industry for being so successful. Just in time ensures to get spare parts from suppliers within just a few hours after ordering. To fulfill these criteria corporations have to be located in the same area increasing their market and service for large corporations.

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. For example, large Multinational Corporations such as Coca-

Cola operate in many different countries and can raise capital where interest rates are lowest and conditions are most suitable.

Capital becomes a main factor when it comes to venture capital. In that case young, fast growing (or not) high tech firms are concerned which usually have not many fixed assets. These firms particularly need access to financial capital and also skilled educated employees.

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.

In order to have a balanced regional growth of industries, both central and state governments in our country offer the package of incentives to entrepreneurs in particular locations. The incentive package may be in the form of exemption from a sales tax and excise duties for a specific period, soft loan from financial institutions, subsidy in electricity charges and investment subsidy. Some of these incentives may tempt to locate the plant to avail these facilities offered.

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

10. Supporting industries and services: Now a day the manufacturing organisation will not make all the components and parts by itself and it subcontracts the work to vendors. So, 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.

2.3.2 Specific Locational Factors for Manufacturing Organisation

DOMINANT FACTORS

Factors dominating location decisions for new manufacturing plants can be broadly classified in six groups. They are listed in the order of their importance as follows.

1. Favourable labour climate
2. Proximity to markets
3. Quality of life
4. Proximity to suppliers and resources
5. Utilities, taxes, and real estate costs

1. Favorable labour climate: A favorable labour climate may be the most important factor in location decisions for labour-intensive firms in industries such as textiles, furniture, and consumer electronics. Labour climate includes wage rates, training requirements, attitudes toward work, worker productivity, and union strength. Many executives consider weak unions or a low probability of union organizing efforts as a distinct advantage.

2. Proximity to markets: After determining where the demand for goods and services is greatest, management must select a location for the facility that will supply that demand. Locating near markets is particularly important when the final goods are bulky or heavy and outbound transportation rates are high. For example, manufacturers of products such as plastic pipe and heavy metals all emphasize proximity to their markets.

3. Quality of life: Good schools, recreational facilities, cultural events, and an attractive lifestyle contribute to quality of life. This factor is relatively unimportant on its own, but it can make the difference in location decisions.

4. Proximity to suppliers and resources: In many companies, plants supply parts to other facilities or rely on other facilities for management and staff support. These require frequent coordination and communication, which can become more difficult as distance increases.

5. Utilities, taxes, and real estate costs: Other important factors that may emerge include utility costs (telephone, energy, and water), local and state taxes, financing incentives offered by local or state governments, relocation costs, and land costs.

SECONDARY FACTORS

There are some other factors needed to be considered, including room for expansion, construction costs, accessibility to multiple modes of transportation, the cost of shuffling people and materials between plants, competition from other firms for the workforce, community attitudes, and many others. For global operations, firms are emphasizing local employee skills and education and the local infrastructure.

2.3.3 Specific Locational Factors for Service Organisation

DOMINANT FACTORS

The factors considered for manufacturers are also applied to service providers, with one important addition — the impact of location on sales and customer satisfaction. Customers usually look about how close a service facility is, particularly if the process requires considerable customer contact.

PROXIMITY TO CUSTOMERS

Location is a key factor in determining how conveniently customers can carry on business with a firm. For example, few people would like to go to remotely located dry cleaner or supermarket if another is more convenient. Thus the influence of location on revenues tends to be the dominant factor.

TRANSPORTATION COSTS AND PROXIMITY TO MARKETS

For warehousing and distribution operations, transportation costs and proximity to markets are extremely important. With a warehouse nearby, many firms can hold inventory closer to the customer, thus reducing delivery time and promoting sales.

LOCATION OF COMPETITORS

One complication in estimating the sales potential at different location is the impact of competitors. Management must not only consider the current location of competitors but also try to anticipate their reaction to the firm's new location. Avoiding areas where competitors are already well established often pays. However, in some industries, such as new-car sales showrooms and fast-food chains, locating near competitors is actually advantageous. The strategy is to create a critical mass, whereby several competing firms clustered in one location attract more customers than the total number who would shop at the same stores at scattered locations. Recognizing this effect, some firms use a follow –the leader strategy when selecting new sites.

SECONDARY FACTORS

Retailers also must consider the level of retail activity, residential density, traffic flow, and site visibility. Retail activity in the area is important, as shoppers often decide on impulse to go shopping or to eat in a restaurant. Traffic flows and visibility are important because businesses' customers arrive in cars. Visibility involves distance from the street and size of nearby buildings and signs. High residential density ensures nighttime and weekend business when the population in the area fits the firm's competitive priorities and target market segment.

2.4**LOCATION THEORIES****ALFRED WEBER'S THEORY OF THE LOCATION OF INDUSTRIES**

Alfred Weber (1868–1958), with the publication of *Theory of the Location of Industries* in 1909, put forth the first developed general theory of industrial location. His model took into account several spatial factors for finding the optimal location and minimal cost for manufacturing plants.

The point for locating an industry that minimizes costs of transportation and labour requires analysis of three factors:

1. The point of optimal transportation based on the costs of distance to the 'material index'—the ratio of weight to intermediate products (raw materials) to finished product.
2. The labour distortion, in which more favourable sources of lower cost of labour may justify greater transport distances.
3. Agglomeration and degglomeration.

Agglomeration or concentration of firms in a locale occurs when there is sufficient demand for support services for the company and labour force, including new investments in schools and hospitals. Also supporting companies, such as facilities that build and service machines and financial services, prefer closer contact with their customers.

Degglomeration occurs when companies and services leave because of over concentration of industries or of the wrong types of industries, or shortages of labour, capital, affordable land, etc. Weber also examined factors leading to the diversification of an industry in the horizontal relations between processes within the plant.

The issue of industry location is increasingly relevant to today's global markets and transnational corporations. Focusing only on the mechanics of the Weberian model could justify greater transport distances for cheap labour and unexploited raw materials. When resources are exhausted or workers revolt, industries move to different countries.

2.5 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

2.5.1 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.

ILLUSTRATION 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?*

Sl. No.	Location factor	Factor rating	Rating	
			Location 1	Location 2
1.	Facility utilization	8	3	5
2.	Total patient per month	5	4	3
3.	Average time per emergency trip	6	4	5
4.	Land and construction costs	3	1	2
5.	Employee preferences	5	5	3

SOLUTION:

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

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

2.5.2 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.

ILLUSTRATION 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?

Sl. No.	Location factor	Weight	Scores	
			Location 1	Location 2
1.	Facility utilization	25	3	5
2.	Total patient km per month	25	4	3
3.	Average time per emergency trip	25	3	3
4.	Land and construction costs	15	1	2
5.	Employee preferences	10	5	3

SOLUTION: The weighted score for this particular site is calculated by multiplying each factor's weight by its score and adding the results:

$$\begin{aligned}\text{Weighed score location 1} &= 25 \times 3 + 25 \times 4 + 25 \times 3 + 15 \times 1 + 10 \times 5 \\ &= 75 + 100 + 75 + 15 + 50 = 315\end{aligned}$$

$$\begin{aligned}\text{Weighed score location 2} &= 25 \times 5 + 25 \times 3 + 25 \times 3 + 15 \times 2 + 10 \times 3 \\ &= 125 + 75 + 75 + 30 + 30 = 335\end{aligned}$$

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

2.5.3 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.

DISTANCE MEASURES

Suppose that a new warehouse is to be located to serve Delhi. It will receive inbound shipments from several suppliers, including one in Ghaziabad. If the new warehouse were located at Gurgaon, what would be the distance between the two facilities? If shipments travel by truck, the distance depends on the highway system and the specific route taken. Computer software is available for calculating the actual mileage between any two locations in the same county. However, 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.

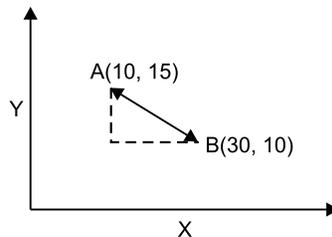


Fig. 2.2 Distance between point A and point B

The point A on the grid represents the supplier's location in Ghaziabad, and the point B represents the possible warehouse location at Gurgaon. The distance between points A and B is the length of the hypotenuse of a right triangle, or

$$d_{AB} = \text{Sqrt} ((X_A - X_B)^2 + (Y_A - Y_B)^2)$$

where d_{AB} = distance between points A and B

X_A = x-coordinate of point A

Y_A = y-coordinate of point A

X_B = x-coordinate of point B

Y_B = y-coordinate of point B

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

$$D_{AB} = |X_A - X_B| + |Y_A - Y_B|$$

CALCULATING A LOAD-DISTANCE SCORE

Suppose that a firm planning a new location wants to select a site that minimizes the distances that loads, particularly the larger ones, must travel to and from the site. Depending on the industry, a load may be shipments from suppliers, between plants, or to customers, or it may be customers or employees travelling to or from the facility. The firm seeks to minimize its load-distance, generally by choosing a location so that large loads go short distances.

To calculate a load-distance for any potential location, we use either of the distance measures and simply multiply the loads flowing to and from the facility by the distances travelled. These loads may be expressed as tones or number of trips per week.

This calls for a practical example to appreciate the relevance of the concept. Let us visit a new Health-care facility, once again.

ILLUSTRATION 3: *The new Health-care facility is targeted to serve seven census tracts in Delhi. The table given below shows the coordinates for the centre of each census tract, along with the projected populations, measured in thousands. Customers will travel from the seven census tract centres to the new facility when they need health-care. Two locations being considered for the new facility are at (5.5, 4.5) and (7, 2), which are the centres of census tracts C and F. Details of seven census tract centres, co-ordinate distances along with the population for each centre are given below. If we use the population as the loads and use rectilinear distance, which location is better in terms of its total load-distance score?*

Sl. No.	Census tract	(x, y)	Population (l)
1	A	(2.5, 4.5)	2
2	B	(2.5, 2.5)	5
3	C	(5.5, 4.5)	10
4	D	(5, 2)	7
5	E	(8, 5)	10
6	F	(7, 2)	20
7	G	(9, 2.5)	14

SOLUTION: Calculate the load-distance score for each location. Using the coordinates from the above table. Calculate the load-distance score for each tract.

Using the formula $D_{AB} = |X_A - X_B| + |Y_A - Y_B|$

Census tract	(x, y)	Population (l)	Locate at (5.5, 4.5)		Locate at (7, 2)	
			Distance (d)	Load-distance	Distance (d)	Load-distance
A	(2.5, 4.5)	2	3 + 0 = 3	6	4.5 + 2.5 = 7	14
B	(2.5, 2.5)	5	3 + 2 = 5	25	4.5 + 0.5 = 5	25
C	(5.5, 4.5)	10	0 + 0 = 0	0	1.5 + 2.5 = 4	40
D	(5, 2)	7	0.5 + 2.5 = 3	21	2 + 0 = 2	14
E	(8, 5)	10	2.5 + 0.5 = 3	30	1 + 3 = 4	40
F	(7, 2)	20	1.5 + 2.5 = 4	80	0 + 0 = 0	0
G	(9, 2.5)	14	3.5 + 2 = 5.5	77	2 + 0.5 = 2.5	35
			Total	239	Total	168

Summing the scores for all tracts 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 census tract F is a better location.

2.5.4 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.

$$C_x = \frac{\sum D_{ix} \cdot W_i}{\sum W_i} \quad C_y = \frac{\sum D_{iy} \cdot W_i}{\sum W_i}$$

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

ILLUSTRATION 4: The new Health-care facility is targeted to serve seven census tracts in Delhi. The table given below shows the coordinates for the centre of each census tract, along with the projected populations, measured in thousands. Customers will travel from the seven census tract centres to the new facility when they need health-care. Two locations being considered for the new facility are at (5.5, 4.5) and (7, 2), which are the centres of census tracts C and F. Details of seven census tract centres, coordinate distances along with the population for each centre are given below. Find the target area's centre of gravity for the Health-care medical facility.

<i>Sl. No.</i>	<i>Census tract</i>	<i>(x, y)</i>	<i>Population (l)</i>
1	A	(2.5, 4.5)	2
2	B	(2.5, 2.5)	5
3	C	(5.5, 4.5)	10
4	D	(5, 2)	7
5	E	(8, 5)	10
6	F	(7, 2)	20
7	G	(9, 2.5)	14

SOLUTION: To calculate the centre of gravity, start with the following information, where population is given in thousands.

<i>Sl. No.</i>	<i>Census tract</i>	<i>(x, y)</i>	<i>Population (l)</i>	<i>Lx</i>	<i>Ly</i>
1	A	(2.5, 4.5)	2	5	9
2	B	(2.5, 2.5)	5	12.5	12.5
3	C	(5.5, 4.5)	10	55	45
4	D	(5, 2)	7	35	14
5	E	(8, 5)	10	80	50
6	F	(7, 2)	20	140	40
7	G	(9, 2.5)	14	126	35
		Total	68	453.50	205.50

Next we find C_x and C_y .

$$C_x = 453.5/68 = 6.67$$

$$C_y = 205.5/68 = 3.02$$

The centre of gravity is (6.67, 3.02). Using the centre of gravity as starting point, managers can now search in its vicinity for the optimal location.

2.5.5 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. 2.3 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:

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

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

$$BEP = \frac{\text{Fixed Cost}}{\text{PV Ratio}} = \frac{\text{Fixed Cost}}{\left\{ \frac{\text{Sales} - \text{Variable Cost}}{\text{Sales}} \right\}} = \frac{F}{\phi} \text{ Rs.}$$

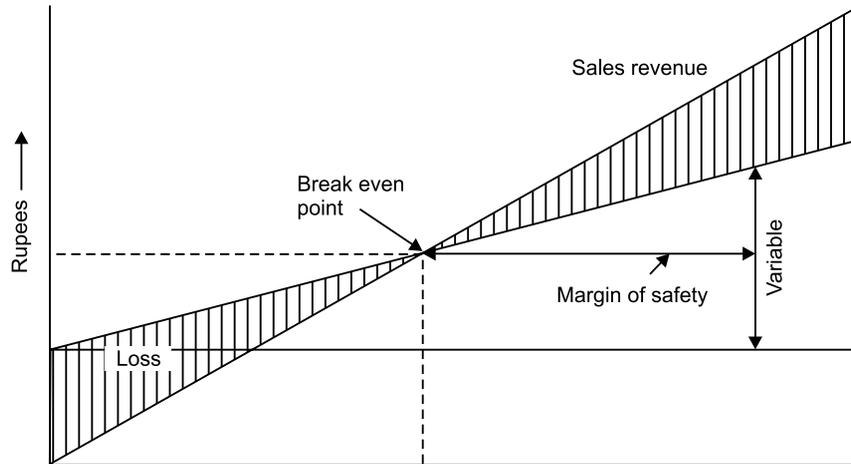


Fig. 2.3 Units of output or percentage of capacity

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.

ILLUSTRATION 5: Potential locations X, Y and Z have the cost structures shown below. 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?

	Location X	Location Y	Location Z
Fixed Costs	Rs. 150,000	Rs. 350,000	Rs. 950,000
Variable Costs	Rs. 10	Rs. 8	Rs. 6

SOLUTION: Solve for the crossover between X and Y:

$$10X + 150,000 = 8X + 350,000$$

$$2X = 200,000$$

$$X = 100,000 \text{ units}$$

Solve for the crossover between Y and Z:

$$8X + 350,000 = 6X + 950,000$$

$$2X = 600,000$$

$$X = 300,000 \text{ units}$$

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

From the graph (Fig. 2.4) 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.

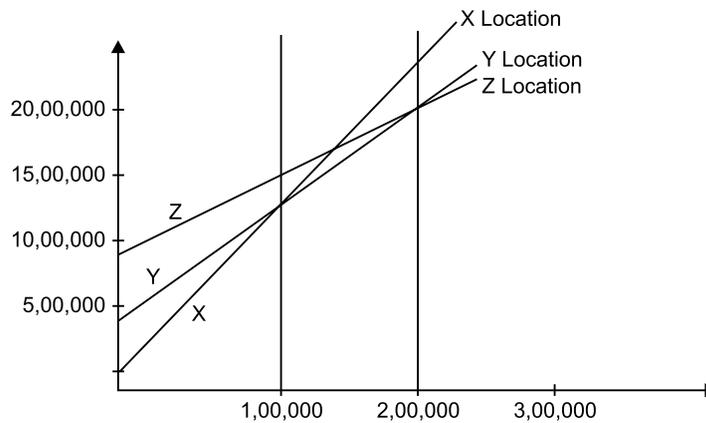


Fig. 2.4 BEP chart

2.6 LOCALATIONAL ECONOMICS

An ideal location is one which results in lowest production cost and least distribution cost per unit. These costs are influenced by a number of factors as discussed earlier. The various costs which decide locational economy are those of land, building, equipment, labour, material, etc. Other factors like community attitude, community facilities and housing facilities will also influence the selection of best location. Economic analysis is carried out to decide as to which locate best location.

The following illustration will clarify the method of evaluation of best layout selection.

ILLUSTRATION 6: From the following data select the most advantageous location for setting a plant for making transistor radios.

	Site X Rs.	Site Y Rs.	Site Z Rs.
(i) Total initial investment	2,00,000	2,00,000	2,00,000
(ii) Total expected sales	2,50,000	3,00,000	2,50,000
(iii) Distribution expenses	40,000	40,000	75,000
(iv) Raw material expenses	70,000	80,000	90,000
(v) Power and water supply expenses	40,000	30,000	20,000
(vi) Wages and salaries	20,000	25,000	20,000
(vii) Other expenses	25,000	40,000	30,000
(viii) Community attitude	Indifferent	Want business	Indifferent
(ix) Employee housing facilities	Poor	Excellent	Good

SOLUTION:

	Site X Rs.	Site Y Rs.	Site Z Rs.
Total expenses			
[Add (iii) (iv) (v) (vi) and (vii)]	1,95,000	2,15,000	2,35,000

$$\text{Rate of return (RoR), \%} = \frac{\text{Total sales} - \text{Total expenses}}{\text{Total investment}} \times 100$$

$$\begin{aligned} \text{RoR for Site X} &= \frac{2,50,000 - 1,95,000}{2,00,000} \times 100 \\ &= \mathbf{27.5\%} \end{aligned}$$

$$\begin{aligned} \text{RoR for Site Y} &= \frac{3,00,000 - 2,15,000}{2,00,000} \times 100 \\ &= \mathbf{42.5\%} \end{aligned}$$

$$\begin{aligned} \text{RoR for Site Z} &= \frac{2,50,000 - 2,35,000}{2,00,000} \times 100 \\ &= \mathbf{7.5\%} \end{aligned}$$

Location Y can be selected because of higher rate of return.

2.7 PLANT LAYOUT

Plant layout refers to the physical arrangement of production facilities. It is the configuration of departments, work centres and equipment in the conversion process. It is a floor plan of the physical facilities, which are used in production.

According to Moore “*Plant layout is a plan of an optimum arrangement of facilities including personnel, operating equipment, storage space, material handling equipment and all other supporting services along with the design of best structure to contain all these facilities*”.

2.7.1 Objectives of Plant Layout

The primary goal of the plant layout is to maximise the profit by arrangement of all the plant facilities to the best advantage of total manufacturing of the product.

The objectives of plant layout are:

1. Streamline the flow of materials through the plant.
2. Facilitate the manufacturing process.
3. Maintain high turnover of in-process inventory.
4. Minimise materials handling and cost.
5. Effective utilisation of men, equipment and space.
6. Make effective utilisation of cubic space.
7. Flexibility of manufacturing operations and arrangements.
8. Provide for employee convenience, safety and comfort.
9. Minimize investment in equipment.
10. Minimize overall production time.
11. Maintain flexibility of arrangement and operation.
12. Facilitate the organizational structure.

2.7.2 Principles of Plant Layout

1. **Principle of integration:** A good layout is one that integrates men, materials, machines and supporting services and others in order to get the optimum utilisation of resources and maximum effectiveness.

2. **Principle of minimum distance:** This principle is concerned with the minimum travel (or movement) of man and materials. The facilities should be arranged such that, the total distance travelled by the men and materials should be minimum and as far as possible straight line movement should be preferred.

3. **Principle of cubic space utilisation:** The good layout is one that utilise both horizontal and vertical space. It is not only enough if only the floor space is utilised optimally but the third dimension, *i.e.*, the height is also to be utilised effectively.

4. **Principle of flow:** A good layout is one that makes the materials to move in forward direction towards the completion stage, *i.e.*, there should not be any backtracking.

5. **Principle of maximum flexibility:** The good layout is one that can be altered without much cost and time, *i.e.*, future requirements should be taken into account while designing the present layout.

6. **Principle of safety, security and satisfaction:** A good layout is one that gives due consideration to workers safety and satisfaction and safeguards the plant and machinery against fire, theft, etc.

7. **Principle of minimum handling:** A good layout is one that reduces the material handling to the minimum.

2.8 CLASSIFICATION OF LAYOUT

Layouts can be classified into the following five categories:

1. Process layout
2. Product layout
3. Combination layout
4. Fixed position layout
5. Group layout

2.8.1 Process Layout

Process layout is recommended for batch production. All machines performing similar type of operations are grouped at one location in the process layout *e.g.*, all lathes, milling machines, etc. are grouped in the shop will be clustered in like groups.

Thus, in process layout the arrangement of facilities are grouped together according to their functions. A typical process layout is shown in Fig. 2.5. The flow paths of material through the facilities from one functional area to another vary from product to product. Usually the paths are long and there will be possibility of backtracking.

Process layout is normally used when the production volume is not sufficient to justify a product layout. Typically, job shops employ process layouts due to the variety of products manufactured and their low production volumes.

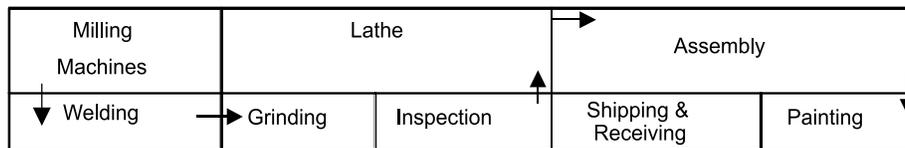


Fig. 2.5 Process layout

Advantages

1. In process layout machines are better utilized and fewer machines are required.
2. Flexibility of equipment and personnel is possible in process layout.
3. Lower investment on account of comparatively less number of machines and lower cost of general purpose machines.
4. Higher utilisation of production facilities.
5. A high degree of flexibility with regards to work distribution to machineries and workers.
6. The diversity of tasks and variety of job makes the job challenging and interesting.
7. Supervisors will become highly knowledgeable about the functions under their department.

Limitations

1. Backtracking and long movements may occur in the handling of materials thus, reducing material handling efficiency.
2. Material handling cannot be mechanised which adds to cost.
3. Process time is prolonged which reduce the inventory turnover and increases the in-process inventory.
4. Lowered productivity due to number of set-ups.
5. Throughput (time gap between in and out in the process) time is longer.
6. Space and capital are tied up by work-in-process.

2.8.2 Product Layout

In this type of layout, machines and auxiliary services are located according to the processing sequence of the product. If the volume of production of one or more products is large, the facilities can be arranged to achieve efficient flow of materials and lower cost per unit. Special purpose machines are used which perform the required function quickly and reliably.

The product layout is selected when the volume of production of a product is high such that a separate production line to manufacture it can be justified. In a strict product layout, machines are not shared by different products. Therefore, the production volume must be sufficient to achieve satisfactory utilisation of the equipment. A typical product layout is shown in Fig. 2.6.

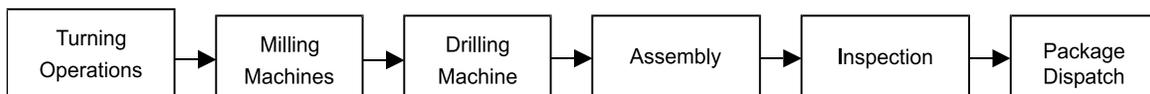


Fig. 2.6 Product layout

Advantages

1. The flow of product will be smooth and logical in flow lines.
2. In-process inventory is less.
3. Throughput time is less.
4. Minimum material handling cost.
5. Simplified production, planning and control systems are possible.
6. Less space is occupied by work transit and for temporary storage.
7. Reduced material handling cost due to mechanised handling systems and straight flow.
8. Perfect line balancing which eliminates bottlenecks and idle capacity.
9. Manufacturing cycle is short due to uninterrupted flow of materials.
10. Small amount of work-in-process inventory.
11. Unskilled workers can learn and manage the production.

Limitations

1. A breakdown of one machine in a product line may cause stoppages of machines in the downstream of the line.
2. A change in product design may require major alterations in the layout.
3. The line output is decided by the bottleneck machine.
4. Comparatively high investment in equipments is required.
5. *Lack of flexibility.* A change in product may require the facility modification.

2.8.3 Combination Layout

A combination of process and product layouts combines the advantages of both types of layouts. A combination layout is possible where an item is being made in different types and sizes. Here machinery is arranged in a process layout but the process grouping is then arranged in a sequence to manufacture various types and sizes of products. It is to be noted that the sequence of operations remains same with the variety of products and sizes. Figure 2.7 shows a combination type of layout for manufacturing different sized gears.

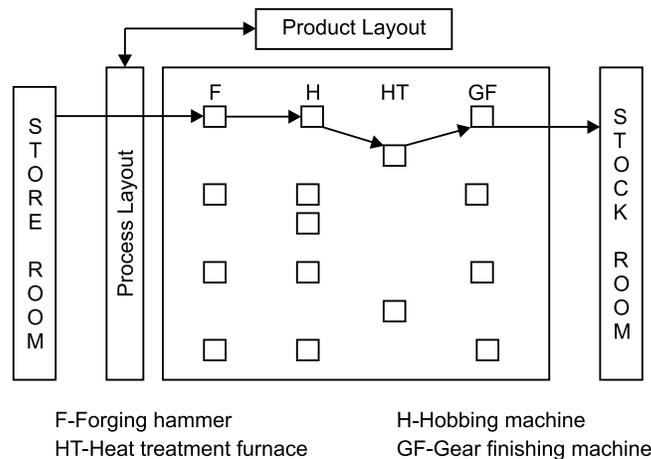


Fig. 2.7 Combination layout for making different types and sizes of gears

2.8.4 Fixed Position Layout

This is also called the **project type** of layout. In this type of layout, the material, or major components remain in a fixed location and tools, machinery, men and other materials are brought to this location. This type of layout is suitable when one or a few pieces of identical heavy products are to be manufactured and when the assembly consists of large number of heavy parts, the cost of transportation of these parts is very high.

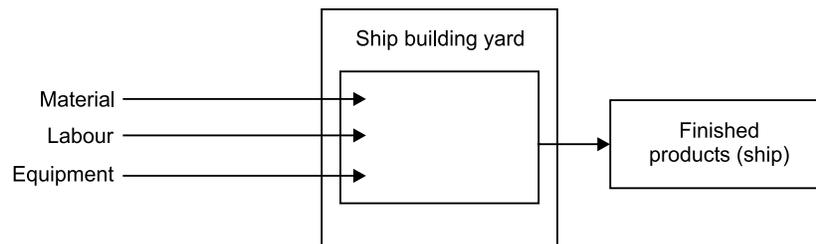


Fig. 2.8 Fixed position layout

Advantages

The major advantages of this type of layout are:

1. Helps in job enlargement and upgrades the skills of the operators.
2. The workers identify themselves with a product in which they take interest and pride in doing the job.
3. Greater flexibility with this type of layout.
4. Layout capital investment is lower.

2.8.5 Group Layout (or Cellular Layout)

There is a trend now to bring an element of flexibility into manufacturing system as regards to variation in batch sizes and sequence of operations. A grouping of equipment for performing a sequence of operations on family of similar components or products has become all the important.

Group technology (GT) is the analysis and comparisons of items to group them into families with similar characteristics. GT can be used to develop a hybrid between pure process layout and pure flow line (product) layout. This technique is very useful for companies that produce variety of parts in small batches to enable them to take advantage and economics of flow line layout.

The application of group technology involves two basic steps; first step is to determine component families or groups. The second step in applying group technology is to arrange the plants equipment used to process a particular family of components. This represents small plants within the plants. The group technology reduces production planning time for jobs. It reduces the set-up time.

Thus **group layout** is a combination of the product layout and process layout. It combines the advantages of both layout systems. If there are m -machines and n -components, in a group layout (Group-Technology Layout), the m -machines and n -components will be divided into distinct

number of machine-component cells (group) such that all the components assigned to a cell are almost processed within that cell itself. Here, the objective is to minimize the intercell movements.

The basic aim of a group technology layout is to identify families of components that require similar of satisfying all the requirements of the machines are grouped into cells. Each cell is capable of satisfying all the requirements of the component family assigned to it.

The layout design process considers mostly a single objective while designing layouts. In process layout, the objective is to minimize the total cost of materials handling. Because of the nature of the layout, the cost of equipments will be the minimum in this type of layout. In product layout, the cost of materials handling will be at the absolute minimum. But the cost of equipments would not be at the minimum if the equipments are not fully utilized.

In-group technology layout, the objective is to minimize the sum of the cost of transportation and the cost of equipments. So, this is called as multi-objective layout. A typical process layout is shown in Fig. 2.9.

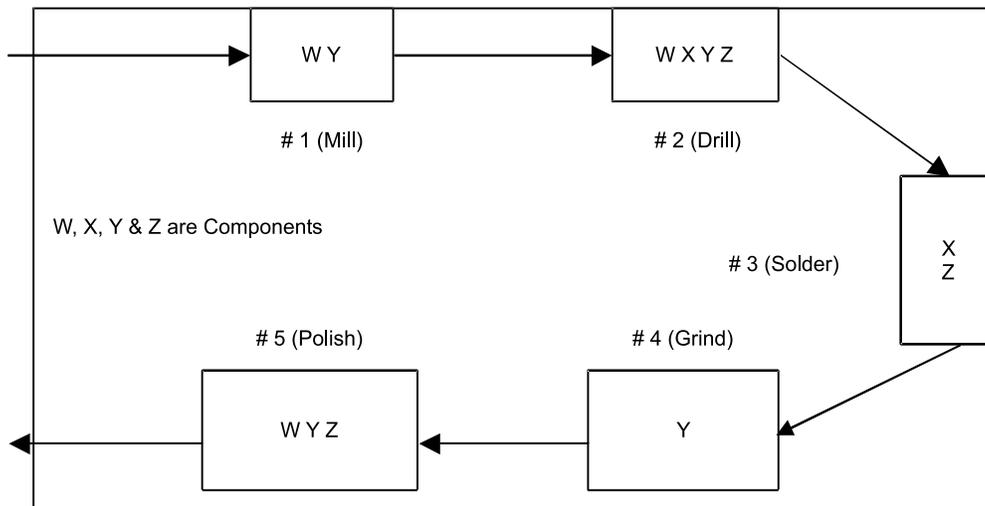


Fig. 2.9 Group layout or Cellular layout

Advantages of Group Technology Layout

Group Technology layout can increase—

1. Component standardization and rationalization.
2. Reliability of estimates.
3. Effective machine operation and productivity.
4. Customer service.

It can decrease the—

1. Paper work and overall production time.
2. Work-in-progress and work movement.
3. Overall cost.

Limitations of Group Technology Layout

This type of layout may not be feasible for all situations. If the product mix is completely dissimilar, then we may not have meaningful cell formation.

2.9 DESIGN OF PRODUCT LAYOUT

In product layout, equipment or departments are dedicated to a particular product line, duplicate equipment is employed to avoid backtracking, and a straight-line flow of material movement is achievable. Adopting a product layout makes sense when the batch size of a given product or part is large relative to the number of different products or parts produced.

Assembly lines are a special case of product layout. In a general sense, the term assembly line refers to progressive assembly linked by some material-handling device. The usual assumption is that some form of pacing is present and the allowable processing time is equivalent for all workstations. Within this broad definition, there are important differences among line types. A few of these are material handling devices (belt or roller conveyor, overhead crane); line configuration (U-shape, straight, branching); pacing (mechanical, human); product mix (one product or multiple products); workstation characteristics (workers may sit, stand, walk with the line, or ride the line); and length of the line (few or many workers). The range of products partially or completely assembled on lines includes toys, appliances, autos, clothing and a wide variety of electronic components. In fact, virtually any product that has multiple parts and is produced in large volume uses assembly lines to some degree.

A more-challenging problem is the determination of the optimum configuration of operators and buffers in a production flow process. A major design consideration in production lines is the assignment of operation so that all stages are more or less equally loaded. Consider the case of traditional assembly lines illustrated in Fig. 2.10.

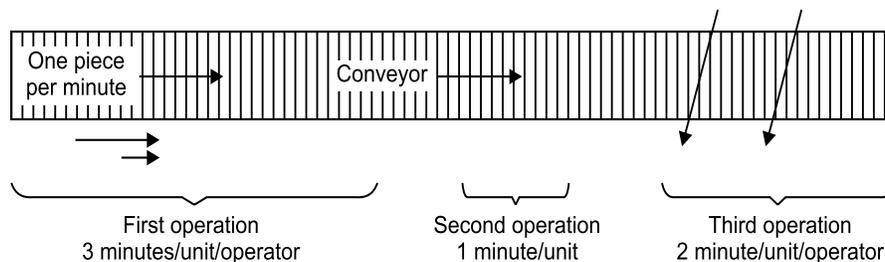


Fig. 2.10 Traditional assembly line

In this example, parts move along a conveyor at a rate of one part per minute to three groups of workstations. The first operation requires 3 minutes per unit; the second operation requires 1 minute per unit; and the third requires 2 minutes per unit. The first workstation consists of three operators; the second, one operator; and the third, two operators. An operator removes a part from the conveyor and performs some assembly task at his or her workstation. The completed part is returned to the conveyor and transported to the next operation. The number of operators at each workstation was chosen so that the line is balanced. Since three operators work simultaneously at the first workstation, on the average one part will be completed each

minute. This is also true for other two stations. Since the parts arrive at a rate of one per minute, parts are also completed at this rate.

Assembly-line systems work well when there is a low variance in the times required to perform the individual subassemblies. If the tasks are somewhat complex, thus resulting in a higher assembly-time variance, operators down the line may not be able to keep up with the flow of parts from the preceding workstation or may experience excessive idle time. An alternative to a conveyor-paced assembly-line is a sequence of workstations linked by gravity conveyors, which act as buffers between successive operations.

LINE BALANCING

Assembly-line balancing often has implications for layout. This would occur when, for balance purposes, workstation size or the number used would have to be physically modified.

The most common assembly-line is a moving conveyor that passes a series of workstations in a uniform time interval called the **workstation cycle time** (which is also the time between successive units coming off the end of the line). At each workstation, work is performed on a product either by adding parts or by completing assembly operations. The work performed at each station is made up of many bits of work, termed tasks, elements, and work units. Such tasks are described by motion-time analysis. Generally, they are grouping that cannot be subdivided on the assembly-line without paying a penalty in extra motions.

The total work to be performed at a workstation is equal to the sum of the tasks assigned to that workstation. The line-balancing problem is one of assigning all tasks to a series of workstations so that each workstation has no more than can be done in the workstation cycle time, and so that the unassigned (idle) time across all workstations is minimized.

The problem is complicated by the relationships among tasks imposed by product design and process technologies. This is called the precedence relationship, which specifies the order in which tasks must be performed in the assembly process.

The steps in balancing an assembly line are:

1. Specify the sequential relationships among tasks using a precedence diagram.
2. Determine the required workstation cycle time C , using the formula

$$C = \frac{\text{Production time per day}}{\text{Required output per day (in units)}}$$

3. Determine the theoretical minimum number of workstations (N_t) required to satisfy the workstation cycle time constraint using the formula

$$N_t = \frac{\text{Sum of task times (T)}}{\text{Cycle time (C)}}$$

4. Select a primary rule by which tasks are to be assigned to workstations, and a secondary rule to break ties.
5. Assign tasks, one at a time, to the first workstation until the sum of the task times is equal to the workstation cycle time, or no other tasks are feasible because of time or sequence restrictions. Repeat the process for workstation 2, workstation 3, and so on until all tasks are assigned.

6. Evaluate the efficiency of the balance derived using the formula

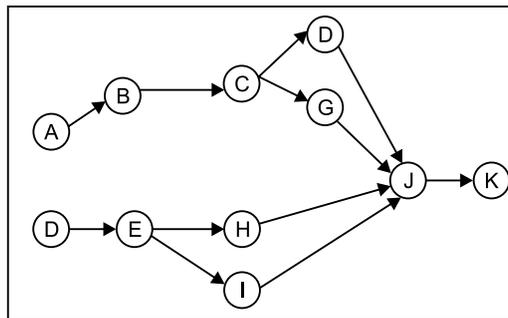
$$\text{Efficiency} = \frac{\text{Sum of task times (T)}}{\text{Actual number of workstations (N}_a\text{)} \times \text{Workstations cycle time (C)}}$$

7. If efficiency is unsatisfactory, rebalance using a different decision rule.

ILLUSTRATION 7: The MS 800 car is to be assembled on a conveyor belt. Five hundred cars are required per day. Production time per day is 420 minutes, and the assembly steps and times for the wagon are given below. Find the balance that minimizes the number of workstations, subject to cycle time and precedence constraints.

Task	Task time (in seconds)	Description	Tasks that must precede
A	45	Position rear axle support and hand fasten	-
B	11	Four screws to nuts	A
C	9	Insert rear axle	B
D	50	Tighten rear axle support screws to nuts	-
E	15	Position front axle assembly and hand	D
F	12	Fasten with four screws to nuts	C
G	12	Tighten front axle assembly screws	C
H	12	Position rear wheel 1 and fasten hubcap	E
I	12	Position rear wheel 2 and fasten hubcap	E
J	8	Position front wheel 1 and fasten hubcap	F, G, H, I
K	9	Position front wheel 2 and fasten hubcap	J

SOLUTION: 1. Draw a precedence diagram as follows:



2. Determine workstation cycle time. Here we have to convert production time to seconds because our task times are in seconds

$$\begin{aligned}
 C &= \frac{\text{Production time per day}}{\text{Required output per day (in units)}} \\
 &= \frac{420 \text{ min} \times 60 \text{ sec}}{500 \text{ cars}} = \frac{25200}{500} = 50.4 \text{ secs}
 \end{aligned}$$

3. Determine the theoretical minimum number of workstations required (the actual number may be greater)

$$N_t = \frac{T}{C} = \frac{195 \text{ seconds}}{50.4 \text{ seconds}} = 3.87 = 4 \text{ (rounded up)}$$

4. Select assignment rules.

(a) Prioritize tasks in order of the largest number of following tasks:

<i>Task</i>	<i>Number of following tasks</i>
A	6
B or D	5
C or E	4
F, G, H, or I	2
J	1
K	0

Our secondary rule, to be invoked where ties exist from our primary rule, is (b) Prioritize tasks in order of longest task time. Note that D should be assigned before B, and E assigned before C due to this tie-breaking rule.

5. Make task assignments to form workstation 1, workstation 2, and so forth until all tasks are assigned. It is important to meet precedence and cycle time requirements as the assignments are made.

<i>Station</i>	<i>Task</i>	<i>Task time (in sec)</i>	<i>Remaining unassigned time (in sec)</i>	<i>Feasible remaining tasks</i>	<i>Task with most followers</i>	<i>Task with longest operation time</i>
Station 1	A	45	5.4	Idle	None	
Station 2	D	50	0.4	Idle	None	
Station 3	B	11	39.4	C, E	C, E	E
	E	15	24.4	C, H, I	C	
	C	9	15.4	F, G, H, I	F, G, H, I	F, G, H, I
	F	12	3.4 idle	None		
Station 4	G	12	38.4	H, I	H, I	H, I
	H	12	26.4	I		
	I	12	14.4	J		
	J	8	6.4 idle	None		
Station 5	K	9	41.4 idle	None		

6. Calculate the efficiency.

$$\text{Efficiency} = \frac{T}{N_d C} = \frac{195}{5 \times 50.4} = .77 \text{ or } 77\%$$

7. Evaluate the solution. An efficiency of 77 per cent indicates an imbalance or idle time of 23 per cent ($1.0 - .77$) across the entire line.

In addition to balancing a line for a given cycle time, managers must also consider four other options: pacing, behavioural factors, number of models produced, and cycle times.

Pacing is the movement of product from one station to the next after the cycle time has elapsed. Paced lines have no buffer inventory. Unpaced lines require inventory storage areas to be placed between stations.

BEHAVIOURAL FACTORS

The most controversial aspect of product layout is behavioural response. Studies have shown that paced production and high specialization lower job satisfaction. One study has shown that productivity increased on unpaced lines. Many companies are exploring job enlargement and rotation to increase job variety and reduce excessive specialization. For example, New York Life has redesigned the jobs of workers who process and evaluate claims applications. Instead of using a production line approach with several workers doing specialized tasks, New York Life has made each worker solely responsible for an entire application. This approach increased worker responsibility and raised morale. In manufacturing, at its plant in Kohda, Japan, Sony Corporation dismantled the conveyor belts on which as many as 50 people assembled camcorders. It set up tables for workers to assemble an entire camera themselves, doing everything from soldering to testing. Output per worker is up 10 per cent, because the approach frees efficient assemblers to make more products instead of limiting them to conveyor belt's speed. And if something goes wrong, only a small section of the plant is affected. This approach also allows the line to match actual demand better and avoid frequent shutdown because of inventory buildups.

NUMBER OF MODELS PRODUCED

A mixed-model line produces several items belonging to the same family. A single-model line produces one model with no variations. Mixed model production enables a plant to achieve both high-volume production and product variety. However, it complicates scheduling and increases the need for good communication about the specific parts to be produced at each station.

CYCLE TIMES

A line's cycle time depends on the desired output rate (or sometimes on the maximum number of workstations allowed). In turn, the maximum line efficiency varies considerably with the cycle time selected. Thus, exploring a range of cycle times makes sense. A manager might go with a particularly efficient solution even if it does not match the output rate. The manager can compensate for the mismatch by varying the number of hours the line operates through overtime, extending shifts, or adding shifts. Multiple lines might even be the answer.

2.10 DESIGN OF PROCESS LAYOUT

The analysis involved in the design of production lines and assembly lines relates primarily to timing, coordination, and balance among individual stages in the process.

For process layouts, the relative arrangement of departments and machines is the critical factor because of the large amount of transportation and handling involved.

PROCEDURE FOR DESIGNING PROCESS LAYOUTS

Process layout design determines the best relative locations of functional work centres. Work centres that interact frequently, with movement of material or people, should be located close together, whereas those that have little interaction can be spatially separated. One approach of designing an efficient functional layout is described below.

1. List and describe each functional work centre.
2. Obtain a drawing and description of the facility being designed.
3. Identify and estimate the amount of material and personnel flow among work centres
4. Use structured analytical methods to obtain a good general layout.
5. Evaluate and modify the layout, incorporating details such as machine orientation, storage area location, and equipment access.

The first step in the layout process is to identify and describe each work centre. The description should include the primary function of the work centre; drilling, new accounts, or cashier; its major components, including equipment and number of personnel; and the space required. The description should also include any special access needs (such as access to running water or an elevator) or restrictions (it must be in a clean area or away from heat).

For a new facility, the spatial configuration of the work centres and the size and shape of the facility are determined simultaneously. Determining the locations of special structures and fixtures such as elevators, loading docks, and bathrooms becomes part of the layout process. However, in many cases the facility and its characteristics are a given. In these situations, it is necessary to obtain a drawing of the facility being designed, including shape and dimensions, locations of fixed structures, and restrictions on activities, such as weight limits on certain parts of a floor or foundation.

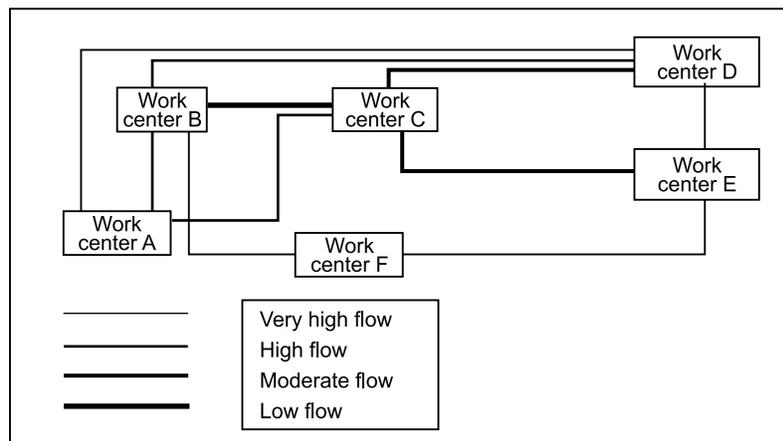


Fig 2.11 Relationship flow diagram

To minimize transport times and material-handling costs, we would like to place close together those work centres that have the greatest flow of materials and people between them.

To estimate the flows between work centres, it is helpful to begin by drawing relationship diagram as shown in Fig. 2.11.

For manufacturing systems, material flows and transporting costs can be estimated reasonably well using historical routings for products or through work sampling techniques applied to workers or jobs. The flow of people, especially in a service system such as a business office or a university administration building, may be difficult to estimate precisely, although work sampling can be used to obtain rough estimates.

The amounts and/or costs of flows among work centres are usually presented using a flow matrix, a flow-cost matrix, or a proximity chart.

1. Flow Matrix

A flow matrix is a matrix of the estimated amounts of flow between each pair of work centres. The flow may be materials (expressed as the number of loads transported) or people who move between centres. Each work centre corresponds to one row and one column, and the element f_{ij} designates the amount of flow from work centre (row) i to work centre (column) j . Normally, the direction of flow between work centres is not important, only the total amount, so f_{ij} and f_{ji} can be combined and the flows represented using only the upper right half of a matrix.

Flow Matrix Table

Work centre										
	A	B	C	D	E	F	G	H	I	
A	-	25	32	0	80	0	30	5	15	Daily flows between work centres
B	-	-	20	10	30	75	0	7	10	
C	-	-	-	0	10	50	45	60	0	
D	-	-	-	-	35	0	25	90	120	
E	-	-	-	-	-	20	80	0	70	
F	-	-	-	-	-	-	0	150	20	
G	-	-	-	-	-	-	-	50	45	
H	-	-	-	-	-	-	-	-	80	
I	-	-	-	-	-	-	-	-	-	

2. Flow-cost Matrix

A basic assumption of facility layout is that the cost of moving materials or people between work centers is a function of distance travelled. Although more complicated cost functions can be accommodated, often we assume that the per unit cost of material and personnel flows between work centres is proportional to the distance between the centres. So for each type of flow between each pair of departments, i and j , we estimate the cost per unit per unit distance, c_{ij} .

Flow-cost Matrix Table

Work centre										Daily cost for flows between work centres (Rs per day per 100 ft)
	A	B	C	D	E	F	G	H	I	
A	-	25	32	0	80	0	30	5	15	
B	-	-	40	10	90	75	0	7	10	
C	-	-	-	0	10	50	45	60	0	
D	-	-	-	-	35	0	50	90	240	
E	-	-	-	-	-	20	80	0	70	
F	-	-	-	-	-	-	0	150	20	
G	-	-	-	-	-	-	-	150	45	
H	-	-	-	-	-	-	-	-	80	
I	-	-	-	-	-	-	-	-	-	

3. Proximity Chart

Proximity charts (relationship charts) are distinguished from flow and flow-cost matrices by the fact that they describe qualitatively the desirability or need for work centres to be close together, rather than providing quantitative measures of flow and cost. These charts are used when it is difficult to measure or estimate precise amounts or costs of flow among work centres. This is common when the primary flows involve people and do not have a direct cost but rather an indirect cost, such as when employees in a corporate headquarters move among departments (payroll, printing, information systems) to carry out their work.

2.11 SERVICE LAYOUT

The major factors considered for service providers, is an impact of location on sales and customer satisfaction. Customers usually look about how close a service facility is, particularly if the process requires considerable customer contact. Hence, service facility layouts should provide for easy entrance to these facilities from the freeways. Well-organized packing areas, easily accessible facilities, well designed walkways and parking areas are some of the requirements of service facility layout.

Service facility layout will be designed based on degree of customer contact and the service needed by a customer. These service layouts follow conventional layouts as required. For example, for car service station, product layout is adopted, where the activities for servicing a car follows a sequence of operation irrespective of the type of car. Hospital service is the best example for adaptation of process layout. Here, the service required for a customer will follow an independent path. The layout of car servicing and hospital is shown in Figs. 2.12 and 2.13.

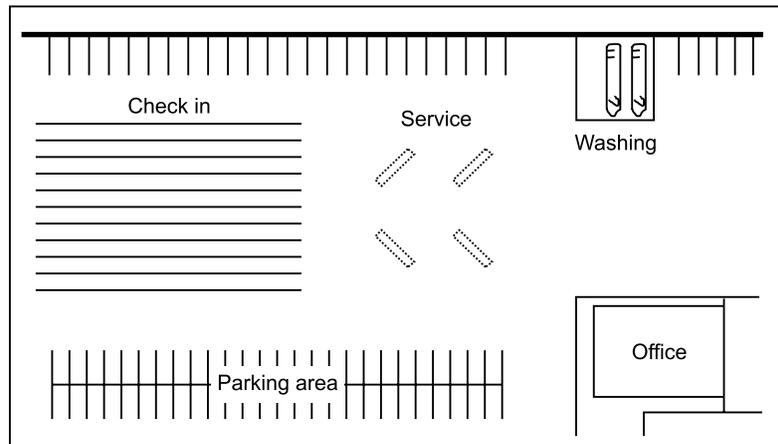


Fig. 2.12 Service layout for car servicing

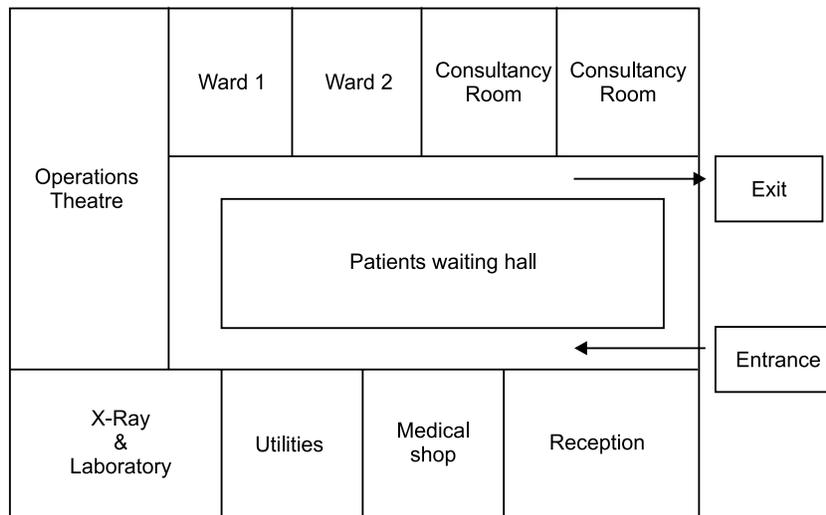


Fig. 2.13 Layout for hospitality service

2.12 ORGANISATION OF PHYSICAL FACILITIES

The following are the most important physical facilities to be organised:

1. Factory building
2. Lighting
3. Climatic conditions
4. Ventilation
5. Work-related welfare facilities

I. FACTORY BUILDING

Factory building is a factor which is the most important consideration for every industrial enterprise. A modern factory building is required to provide protection for men, machines, materials, products

or even the company's secrets. It has to serve as a part of the production facilities and as a factor to maximise economy and efficiency in plant operations. It should offer a pleasant and comfortable working environment and project the management's image and prestige. Factory building is like skin and bones of a living body for an organisation. It is for these reasons that the factory building acquires great importance.

Following factors are considered for an Industrial Building:

- A. Design of the building.
- B. Types of buildings.

A. Design of the Building

The building should be designed so as to provide a number of facilities—such as lunch rooms, cafeteria, locker rooms, crèches, libraries, first-aid and ambulance rooms, materials handling facilities, heating, ventilation, air-conditioning, etc. Following factors are considerations in the designing of a factory building:

1. **Flexibility:** Flexibility is one of the important considerations because the building is likely to become obsolete and provides greater operating efficiency even when processes and technology change. Flexibility is necessary because it is not always feasible and economical to build a new plant, every time a new firm is organised or the layout is changed. With minor alternations, the building should be able to accommodate different types of operations.

2. **Product and equipment:** The type of product that is to be manufactured, determines column-spacing, type of floor, ceiling, heating and air-conditioning. A product of a temporary nature may call for a less expensive building and that would be a product of a more permanent nature. Similarly, a heavy product demands a far more different building than a product which is light in weight.

3. **Expansibility:** Growth and expansion are natural to any manufacturing enterprises. They are the indicators of the prosperity of a business. The following factors should be borne in mind if the future expansion of the concern is to be provided for:

- (i) The *area of the land* which is to be acquired should be large enough to provide for the future expansion needs of the firm and accommodate current needs.
- (ii) The *design of the building* should be in a rectangular shape. Rectangular shapes facilitate expansion on any side.
- (iii) If *vertical expansion* is expected, strong foundations, supporters and columns must be provided.
- (iv) If *horizontal expansion* is expected, the side walls must be made non-load-bearing to provide for easy removal.

4. **Employee facilities and service area:** Employee facilities must find a proper place in the building design because they profoundly affect the morale, comfort and productivity. The building plan should include facilities for lunch rooms, cafeteria, water coolers, parking area and the like. The provision of some of these facilities is a legal requirement. Others make good working conditions possible. And a good working condition is good business.

Service areas, such as the tool room, the supervisor's office, the maintenance room, receiving and dispatching stations, the stock room and facilities for scrap disposal, should also be included in the building design.

B. Types of Buildings

Industrial buildings may be grouped under three types:

1. Single-storey buildings,
2. Multi-storey buildings

The decision on choosing a suitable type for a particular firm depends on the manufacturing process and the area of land and the cost of construction.

1. SINGLE-STOREY BUILDINGS

Most of the industrial buildings manufacturing which are now designed and constructed are single storeyed, particularly where lands are available at reasonable rates. Single-storey buildings offer several operating advantages. A single-storey construction is preferable when materials handling is difficult because the product is big or heavy, natural lighting is desired, heavy floor loads are required and frequent changes in layout are anticipated.

Advantages

Advantages of single-storey building are:

1. There is a greater flexibility in layout and production routing.
2. The maintenance cost resulting from the vibration of machinery is reduced considerably because of the housing of the machinery on the ground.
3. Expansion is easily ensured by the removal of walls.
4. The cost of transportation of materials is reduced because of the absence of materials handling equipment between floors.
5. All the equipment is on the same level, making for an easier and more effective layout supervision and control.
6. Greater floor load-bearing capacity for heavy equipment is ensured.
7. The danger of fire hazards is reduced because of the lateral spread of the building.

Limitations

Single-storey buildings suffer from some limitations. These are:

1. High cost of land, particularly in the city.
2. High cost of heating, ventilating and cleaning of windows.
3. High cost of transportation for moving men and materials to the factory which is generally located far from the city.

2. MULTI-STOREY BUILDINGS

Schools, colleges, shopping complexes, and residences, and for service industries like Software, BPO etc. multi-storey structures are generally popular, particularly in cities. Multi-storey buildings are useful in manufacture of light products, when the acquisition of land becomes difficult and expensive and when the floor load is less.

Advantages

When constructed for industrial use, multi-storey buildings offer the following advantages:

1. Maximum operating floor space (per sq. ft. of land). This is best suited in areas where land is very costly.
2. Lower cost of heating and ventilation.
3. Reduced cost of materials handling because the advantage of the use of gravity for the flow of materials.

Limitations

Following are the disadvantages of multi-storey building:

1. Materials handling becomes very complicated. A lot of time is wasted in moving them between floors.
2. A lot of floor space is wasted on elevators, stairways and fire escapes.
3. Floor load-bearing capacity is limited, unless special construction is used, which is very expensive.
4. Natural lighting is poor in the centres of the shop, particularly when the width of the building is somewhat great.
5. Layout changes cannot be effected easily and quickly.

Generally speaking, textile mills, food industries, detergent plants, chemical industries and software industry use these types of buildings.

II. LIGHTING

It is estimated that 80 per cent of the information required in doing job is perceived visually. Good visibility of the equipment, the product and the data involved in the work process is an essential factor in accelerating production, reducing the number of defective products, cutting down waste and preventing visual fatigue and headaches among the workers. It may also be added that both inadequate visibility and glare are frequently causes accidents.

In principle, lighting should be adapted to the type of work. However, the level of illumination, measured in should be increased not only in relation to the degree of precision or miniaturization of the work but also in relation to the worker's age. The accumulation of dust and the wear of the light sources cut down the level of illumination by 10–50 per cent of the original level. This gradual drop in the level should therefore be compensated for when designing the lighting system. Regular cleaning of lighting fixture is obviously essential.

Excessive contrasts in lighting levels between the worker's task and the general surroundings should also be avoided. The use of natural light should be encouraged. This can be achieved by installing windows that open, which are recommended to have an area equal to the time of day, the distance of workstations from the windows and the presence or absence of blinds. For this reason it is essential to have artificial lighting, will enable people to maintain proper vision and will ensure that the lighting intensity ratios between the task, the surrounding objects and the general environment are maintained.

CONTROL OF LIGHTING

In order to make the best use of lighting in the work place, the following points should be taken into account:

1. For uniform light distribution, install an independent switch for the row of lighting fixtures closest to the windows. This allows the lights to be switched on and off depending on whether or not natural light is sufficient.
2. To prevent glare, avoid using highly shiny, glossy work surfaces.
3. Use localized lighting in order to achieve the desired level for a particular fine job.
4. Clean light fixtures regularly and follow a maintenance schedule so as to prevent flickering of old bulbs and electrical hazards due to worn out cables.
5. Avoid direct eye contact with the light sources. This is usually achieved by positioning them property. The use of diffusers is also quite effective.

III. CLIMATIC CONDITIONS

Control of the climatic conditions at the workplace is paramount importance to the workers health and comfort and to the maintenance of higher productivity. With excess heat or cold, workers may feel very uncomfortable, and their efficiency drops. In addition, this can lead to accidents.

This human body functions in such a way as to keep the central nervous system and the internal organs at a constant temperature. It maintains the necessary thermal balance by continuous heat exchange with the environment. It is essential to avoid excessive heat or cold, and wherever possible to keep the climatic conditions optimal so that the body can maintain a thermal balance.

WORKING IN A HOT ENVIRONMENT

Hot working environments are found almost everywhere. Work premise in tropical countries may, on account of general climatic conditions, be naturally hot. When source of heat such as furnaces, kilns or hot processes are present, or when the physical workload is heavy, the human body may also have to deal with excess heat. It should be noted that in such hot working environments sweating is almost the only way in which the body can lose heat. As the sweat evaporates, the body cools. There is a relationship between the amount and speed of evaporation and a feeling of comfort. The more intense the evaporation, the quicker the body will cool and feel refreshed. Evaporation increases with adequate ventilation.

WORKING IN A COLD ENVIRONMENT

Working in cold environments was once restricted to non-tropical or highly elevated regions. Now as a result of modern refrigeration, various groups of workers, even in tropical countries, are exposed to a cold environment.

Exposure to cold for short periods of time can produce serious effects, especially when workers are exposed to temperatures below 10°C The loss of body heat is uncomfortable and quickly affects work efficiency. Workers in cold climates and refrigerated premises should be well protected against the cold by wearing suitable clothes, including footwear, gloves and, most importantly, a hat. Normally, dressing in layers traps dead air and serves as an insulation layer, thus keeping the worker warmer.

CONTROL OF THE THERMAL ENVIRONMENT

There are many ways of controlling the thermal environment. It is relatively easy to assess the effects of thermal conditions, especially when excessive heat or cold is an obvious problem. To solve the problem, however, consistent efforts using a variety of available measures are usually necessary. This is because the problem is linked with the general climate, which greatly affects the workplace climate, production technology, which is often the source of heat or cold and varying conditions of the work premises as well as work methods and schedules. Personal factors such as clothing, nutrition, personal habits, and age and individual differences in response to the given thermal conditions also need to be taken into account in the attempt to attain the thermal comfort of workers.

In controlling the thermal environment, one or more of the following **principles** may be applied:

1. Regulating workroom temperature by preventing outside heat or cold from entering (improved design of the roof, insulation material or installing an air-conditioned workroom. Air-conditioning is costly, especially in factories. But it is sometimes a worthwhile investment if an appropriate type is chosen);
2. provision of ventilation in hot workplaces by increasing natural ventilating through openings or installing ventilation devices;
3. separation of heat sources from the working area, insulation of hot surfaces and pipes, or placement of barriers between the heat sources and the workers;
4. control of humidity with a view to keeping it at low levels, for example by preventing the escape of steam from pipes and equipment;
5. Provision of adequate personal protective clothing and equipment for workers exposed to excessive radiant heat or excessive cold (heat-protective clothing with high insulation value may not be recommended for jobs with long exposure to moderate or heavy work as it prevents evaporative heat loss);
6. Reduction of exposure time, for example, by mechanization, remote control or alternating work schedules;
7. Insertion of rest pauses between work periods, with comfortable, if possible air-conditioned, resting facilities;
8. Ensuring a supply of cold drinking-water for workers in a hot environment and of hot drinks for those exposed to a cold environment.

IV. VENTILATION

Ventilation is the dynamic parameter that complements the concept of air space. For a given number of workers, the smaller the work premises the more should be the ventilation.

Ventilation differs from air circulation. Ventilation replaces contaminated air by fresh air, whereas as the air-circulation merely moves the air without renewing it. Where the air temperature and humidity are high, merely to circulate the air is not only ineffective but also increases heat absorption. Ventilation disperses the heat generated by machines and people at work. Adequate ventilation should be looked upon as an important factor in maintaining the worker's health and productivity.

Except for confined spaces, all working premises have some minimum ventilation. However, to ensure the necessary air flow (which should not be lower than 50 cubic metres of air per hour per worker), air usually needs to be changed between four to eight times per hour in offices or for sedentary workers, between eight and 12 times per hour in workshops and as much as 15 to 30 or more times per hour for public premises and where there are high levels of atmospheric pollution or humidity. The air speed used for workplace ventilation should be adapted to the air temperature and the energy expenditure: for sedentary work it should exceed 0.2 metre per second, but for a hot environment the optimum speed is between 0.5 and 1 metre per second. For hazardous work it may be even higher. Certain types of hot work can be made tolerable by directing a stream of cold air at the workers.

Natural ventilation, obtained by opening windows or wall or roof airvents, may produce significant air flows but can normally be used only in relatively mild climates. The effectiveness of this type of ventilation depends largely on external conditions. Where natural ventilation is inadequate, artificial ventilation should be used. A choice may be made between a blown-air system, an exhaust air system or a combination of both ('push-pull' ventilation). Only 'push-pull' ventilation systems allow for better regulation of air movement.

V. WORK-RELATED WELFARE FACILITIES

Work-related welfare facilities offered at or through the workplace can be important factors. Some facilities are very basic, but often ignored, such as drinking-water and toilets. Others may seem less necessary, but usually have an importance to workers far greater than their cost to the enterprise.

1. DRINKING WATER

Safe, cool drinking water is essential for all types of work, especially in a hot environment. Without it fatigue increases rapidly and productivity falls. Adequate drinking water should be provided and maintained at convenient points, and clearly marked as "Safe drinking water". Where possible it should be kept in suitable vessels, renewed at least daily, and all practical steps taken to preserve the water and the vessels from contamination.

2. SANITARY FACILITIES

Hygienic sanitary facilities should exist in all workplaces. They are particularly important where chemicals or other dangerous substances are used. Sufficient toilet facilities, with separate facilities for men and women workers, should be installed and conveniently located. Changing-rooms and cloakrooms should be provided. Washing facilities, such as washbasins with soap and towels, or showers, should be placed either within changing-rooms or close by.

3. FIRST-AID AND MEDICAL FACILITIES

Facilities for rendering first-aid and medical care at the workplace in case of accidents or unforeseen sickness are directly related to the health and safety of the workers. First-aid boxes should be clearly marked and conveniently located. They should contain only first-aid requisites of a prescribed standard and should be in the charge of qualified person. Apart from first-aid boxes, it is also desirable to have a stretcher and suitable means to transport injured persons to a centre where medical care can be provided.

4. REST FACILITIES

Rest facilities can include seat, rest-rooms, waiting rooms and shelters. They help workers to recover from fatigue and to get away from a noisy, polluted or isolated workstation. A sufficient number of suitable chairs or benches with backrests should be provided and maintained, including seats for occasional rest of workers who are obliged to work standing up. Rest-rooms enable workers to recover during meal and rest breaks.

5. FEEDING FACILITIES

It is now well recognized that the health and work capacity of workers to have light refreshments are needed. A full meal at the workplace is necessary when the workers live some distance away and when the hours of work are so organized that the meal breaks are short. A snack bar, buffet or mobile trolleys can provide tea, coffee and soft drinks, as well as light refreshments. Canteens or a restaurant can allow workers to purchase a cheap, well-cooked and nutritious meal for a reasonable price and eat in a clean, comfortable place, away from the workstation.

6. CHILD-CARE FACILITIES

Many employers find that working mothers are especially loyal and effective workers, but they often face the special problems of carrying for children. It is for this reason that child-care facilities, including crèches and day-care centres, should be provided. These should be in secure, airy, clean and well lit premises. Children should be looked after properly by qualified staff and offered food, drink education and play at very low cost.

7. RECREATIONAL FACILITIES

Recreational facilities offer workers the opportunity to spend their leisure time in activities likely to increase physical and mental well-being. They may also help to improve social relations within the enterprise. Such facilities can include halls for recreation and for indoor and outdoor sports, reading-rooms and libraries, clubs for hobbies, picnics and cinemas. Special educational and vocational training courses can also be organized.

EXERCISES

Section A

1. What do you mean by plant location?
2. What is virtual proximity?
3. What is virtual factory?
4. What is agglomeration?
5. What is degglomeration?
6. What is plant layout?
7. Mention any four objectives of plant layout.

Section B

1. Explain different operations strategies in case of location choice for existing organisation.
2. Explain the factors to be considered while selecting the location for the new organisation.
3. Explain the reasons for global or foreign location.

4. Explain the Alfred Weber's theory of the location of industries.
5. Explain the objectives of plant layout.
6. Explain the main principles of plant layout.
7. Explain the factors considered for an industrial building.

Section C

1. Explain the need for selecting a suitable location.
2. Explain the factors influencing plant location.
3. Explain the different types of layouts.
4. Explain the physical facilities required in an organisation/factory.

Skill Development

FAST FOOD RESTAURANT VISIT: Get the information for the following questions:

1. The locational factors considered for establishing the enterprise.
2. Strategy adopted for identifying the location [Ex: factor rating, load, distances method etc.]
3. Type of layout.
4. Physical facilities existing [line lighting ventilators, type of building etc.]