PLANT LAYOUT

Defnition:

"Plant layout is the optimum arrangement of different facilities including man, machines, equipment, and material etc, showing the space allocated for material movement, storage and all supporting activities from the receipt of raw material to the shipping of the finished goods for an overall economy of production"

2 CHAPTER

FACILITIES LOCATION, PLANT LAYOUT, MATERIAL HANDLING AND CAPACITY PLANNING

INSIDE THIS CHAPTER

2.1. Facility Location (Introduction)
2.2. Plant Layout
2.3. Material Handling
2.4. Capacity Planning

2.1. FACILITY LOCATION (INTRODUCTION)

Traditionally, location has always meant as industrial plant/factory location down the ages, however, the concept of **plant location** has now been generalised into that of **facility location** since the facility could include a production operation or service system. The term **plant** has been used as synonymous to a factory, manufacturing unit or assembly unit which could include fertiliser, steel, paper, cement, rice milling plants, textile, jute, sugar mills, rubber factories, breweries, refineries, thermal or hydro-electric nuclear power station etc. However, with the enlarged scope of a facility, this term can now be used to refer to banks, hospitals, blood banks, fire stations, police stations, warehouses, godowns, depots, recreation centres and beauty parlours etc.

Facility location decisions are strategic, long term and non-repetitive in nature. Without sound and careful location planning in the beginning itself, the new facility may pose continuous operating disadvantages, for the future operation. A right selection of a plant location can make and a wrong one can mar an organisation. Location decisions are affected by many factors such as the technology used, the capacity, the financial position, the work force required and also by economic, political and social conditions in the various localities. The efficiency, effectiveness, productivity and profitability of the facility are also affected by the location decision. The facilities location problem is concerned primarily with the best location depending on the appropriate criteria of effectiveness. The following are some of the important factors affecting plant location.

Factors Affecting Plant Location

(1) Input Considerations

(*a*) Material—Quantity, quality, cost and regular supply

(*b*) Land—Site availability and costs, cost of construction, constructional regulations.

(*c*) Equipment—Availability and cost

(*d*) Plant utilities—Gas, electricity, coal, water etc. availability and cost

(*e*) Labour—Availability, supply, skill, wage rates, unionization

(*f*) Capital—Equity and debt potential, banking facilities

(2) Processing considerations

(*a*) Production analysis—Educational and research facilities

(*b*) Process analysis—Engineering and consultancy

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(c) Forecasting and scheduling—Data resources and capabilities
(d) Production control—Inventory storage and future expansion
(e) Maintenance—Service and repair facilities
(f) Cost control—Accounting and credit facilities
(g) Presence of related industries.

(3) Output considerations
(a) Distribution—Distribution and storage facilities.
(b) Transportation—Facilities and costs
(c) Present and future market potential
(d) Local rates and taxes

(4) Other considerations
(a) Community attitude towards industry and company
(b) Public and community services—educational, recreational, housing, medical and cultural etc.
(c) Stockholder interests
(d) Organizational decentralisation policies
(e) Environmental standards—Air, water, zoning and building codes
(f) Political situation

2.1.1. When Does a Location Decision Arise ?

A location decision arises due to the various reasons listed below :

(1) It may arise when a new facility is to be established.

(2) In some cases, the facility or plant operations and subsequent expansion are restricted by a poor site, thereby necessitating the setting up of the facility at a new site.

(3) The growing volume of business makes it advisable to establish additional facilities in new territories.

(4) Decentralisation and dispersal of industries reflected in the Industrial Policy resolution so as to achieve an overall development of a developing country, would necessitate a location decision at a macro level.

(5) It could happen that the original advantages of the plant have been overweighed due to new developments.

(6) New economic, social, legal or political factors could suggest a change of location of the existing plant.

Whenever the plant location decision arises, it deserves careful attention because of the long term consequences and any mistake in selection of a proper location could prove to be costly. Poor location could be a constant source of

(i) higher cost
(ii) higher investment
(iii) difficult marketing and transportation
(iv) dissatisfied and frustrated employees and consumers

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(v) frequent interruptions of production

(vi) abnormal wastages

(vii) delays in committed dates of supply

(viii) substandard quality

(ix) denied advantages of geographical specialisation and so on.

Once a facility is set up at a location, it is very difficult to shift later to a better location because of numerous economic, political and sociological reasons.

Economic reasons could include total costs, profits, availability of raw materials, labour, power, transportation facilities and market etc.

Social reasons could include employee welfare and employment opportunities etc.

Political reasons could be because of pursuance of a policy of decentralisation regional and developmental planning especially in a developing country like India. There could be security considerations on the risk of military invasions, sabotage from anti-social elements etc. and some may be prone to natural calamities like floods, droughts, and earthquake etc. Policy matters like anti-pollution etc. would have to be given their due consideration.

Weber's Analysis

Alfred Weber's analysis was one of the first attempt to base location decisions on the transport cost of the raw material which was least mobile. He categorised raw materials into (*a*) **Ubiquities**—to denote those raw materials which are available almost everywhere like sand, soil and water etc. and (*b*) **Localised materials** having specific locations. These are further divided into pure material which contributes nearly the total weight of it to the finished goods and gross material which contributes only a small fraction of total weight to the finished goods. It is obvious that ubiquities hardly influence the decision of location. Weber formulated the following material index :

$$\text{Material Index (M.I.)} = \frac{\text{Weight of the localised material used in the finished product}}{\text{Weight of the finished product}}$$

If M.I. > 1, then location should be nearer to the source of the raw material

If M.I. < 1, then the location should be nearer to the market.

The common-sense involved in the above conclusion is unquestionable but such an approach tacitly assumes the existence of a static point of the lowest transportation cost for the raw material.

2.1.2. Steps in the Facility Location Study

In the following two phases the location studies are usually made

(*i*) the general territory selection phase

(*ii*) the exact site/community selection phase among those available in the general locale.

The considerations vary at the two levels, though there is substantial overlap is shown in the Table 2.1.

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Table 2.1. Overlap of consideration of factors in the two stages of facility location.

Location factors	*Phase I* *General territory selection*	*Phase II* *Particular selection of site and community*
(1) Market	*	—
(2) Raw materials	*	—
(3) Power	*	*
(4) Transportation	*	*
(5) Climate and fuel	*	—
(6) Labour and wages	*	*
(7) Laws and taxation	*	*
(8) Community services and attitude	—	*
(9) Water and waste	—	*
(10) Ecology and pollution	—	*
(11) Capital availability	*	*
(12) Vulnerability to enemy attack	*	*

An inter-disciplinary team consisting of economists, accountants, geographers, town planners, lawyers, marketing experts, politicians, executives, industrial engineers, defence analysts and ecologists etc. should be set-up for undertaking location studies.

Phase I. Territory Selection

The following are some of the important factors that influence the selection decision for the general territory/region/area selection.

(*a*) **Markets.** There has to be some customer/market for your product/service. The market growth potential and the location of competitors are important factors that could influence the location. Locating a plant or facility near to the market is preferred if promptness in service is required, if the product is fragile, or is susceptible to spoilage like glass articles, bangles, ceramic goods, fresh breads, jam, jelly, pickles etc. Moreover, if the product is relatively inexpensive and transportation costs add substantially to the cost, a location close to the market is desirable. Assembly type industries also tend to locate near markets.

(*b*) **Raw Materials and Supplies.** Sometimes accessibility to vendors/suppliers of raw materials, part supplies, tools, equipment etc. may be very important. The issue here is promptness and regularity of delivery and inward freight cost minimization.

If the raw material is bulky or low in cost, or if it is greatly reduced in bulk viz. transformed into various products and by-products, if it is perishable and processing makes it less so, then location near raw materials sources is important. If raw materials come from a variety of locations, the plant/facility may be situated so as to minimise total transportation costs. The costs vary depending upon specific routes, mode of transportation and specific product classifications.

Transportation Facilities. Adequate transportation facilities are essential for the economic operation of a production system. For companies that produce or buy heavy bulky and low value per ton commodities, water transportation could be an important factors in locating plants. It can be seen that civilisations grew along rivers/ waterways etc. Many facilities/plants are located along river banks.

Manpower Supply. The availability of skilled manpower, the prevailing wage pattern, living costs and the industrial relations situation influence the location.

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Infrastructure. This factor refers to the availability and reliability of power, water, fuel and communication facilities in addition to transportation facilities.

Legislation and Taxation. Factors such as financial and other incentives for new industries in backward areas or no-industry-district centres, exemption from certain state and local taxes, octroi etc. are important.

Climate. Climatic factors could dictate the location of certain type of industries like textile industry which requires high humidity zones.

Phase II. Site/Community Selection

Having selected the general territory/region, next we would have to go in for site/community selection. Let us discuss some factors relevant for this stage.

Community Facilities. These involve factors such as quality of life which in turn depends on availability of facilities like schools, places of worship, medical services, police and fire stations, cultural, social and recreation opportunities, housing, good streets and good communication and transportation facilities.

Community Attitudes. These can be difficult to evaluate. Most communities usually welcome setting up of a new industry especially since it would provide opportunities to the local people directly or indirectly. However, in case of polluting, or 'dirty' industries, they would try their utmost to locate them as far away as possible. Sometimes because of prevailing law and order situation, companies have been forced to relocate their units. The attitude of people as well as the state government has an impact on industrial location.

Waste Disposal. The facilities required for the disposal of process waste including solid, liquid and gaseous effluents need to be considered. The plant should be positioned so that prevailing winds carry any fumes away from populated areas and so that waste may be disposed off properly and at reasonable expense.

Ecology and Pollution. These days there is a great deal of awareness towards maintenance of natural ecological balance. There are quite a few agencies propagating the concepts to make the society at large more conscious of the dangers of certain avoidable actions.

Site Size. The plot of land must be large enough to hold the proposed plant and parking and access facilities and provide room for future expansion. These days a lot of industrial areas/parks are being earmarked in which certain standard sheds are being provided to entrepreneurs (especially small scale ones).

Topography. The topography, soil structure and drainage must be suitable. If considerable land improvement is required, low priced land might turn out to be expensive.

Transportation Facilities. The site should be accessible by road and rail preferably. The dependability and character of the available transport carriers, frequency of service and freight and terminal facilities are also worth considering.

Supporting Industries and Services. The availability of supporting services such as tool rooms, plant services etc. need to be considered.

Land Costs. These are generally of lesser importance as they are non-recurring and possibly make up a relatively small proportion of the total cost of locating a new plant. Generally sperking, the site will be in a city, suburb or country location. In general, the location for large-scale industries should be in rural areas, which helps in regional development also. It is seen that once a large industry is set up (or even if a decision to this effect has been taken), a lot of infrastructure develops around it as a result of the location decision. As for the location of medium scale industries, these could be preferably in the suburban/semi-urban areas where the advantages of urban and rural areas are available. For the Small-Scale Industries, the location could be urban areas where the infrastructural facilities are already available. However, in real life, the situation is somewhat paradoxical as people, with money and means, are usually in the cities and would like to locate the units in the city itself.

Some of the industrial needs and characteristics that tend to favour each of these locales are now discussed.

Requirements govern choice **of a city location** are :

1. Availability of adequate supply of labour force.
2. High proportion of skilled employees.
3. Rapid public transportation and contact with suppliers and customers.
4. Small plant site or multi-floor operations.
5. Processes heavily dependent on city facilities and utilities.
6. Good communication facilities like telephone, telex, post offices.
7. Good banking and health care delivery systems.

Requirements governing the choice **of a suburban location** are :

1. Large plant site close to transportation or population centre.
2. Free from some common city building zoning (industrial areas) and other restrictions.
3. Freedom from higher parking and other city taxes etc.
4. Labour force required resides close to plant.
5. Community close to, but not in, large population centre.
6. Plant expansion easier than in the city.

Requirements governing the choice **of a country/rural location** are :

1. Large plant site required for either present demands or expansion.
2. Dangerous production processes.
3. Lesser effort required for anti-pollution measures.
4. Large volume of relatively clean water.
5. Lower property taxes, away from Urban Land Ceiling Act restrictions.
6. Protection against possible sabotage or for a secret process.
7. Balanced growth and development of a developing or underdeveloped area.
8. Unskilled labour force required.
9. Low wages required to meet competition.

2.1.3. Subjective, Quantitative and Semi-Quantitative Techniques of Plant Location

Three subjective techniques used for facility location are :

(*i*) Industry precedence (*ii*) Preferential factor (*iii*) Dominant factor.

(*i*) **Industry Precedence.** Here the basic assumption is that if a location was best for similar forms in the past, it must be the best for us now also and in future too. As such there is no need for conducting a detailed location study and the location choice is thus subject to the principle of precedence—good or bad.

(*ii*) **Preferential Factor.** Here the location decision is dictated by a personal factor. It depends on the individual whims and preferences *e.g.*, if one belongs to a particular state, he may like to locate his unit only in that state. Such personal factors may not take into account the factors of cost, investment or profit in making as final decision. This could hardly be called a professional approach though such methods are probably more common in practice in our country than generally recognized.

(*iii*) **Dominant Factor.** In some cases of plant location there could be certain dominant factors (in contrast to the preferential factor) which could influence the location decisions. In a true dominant sense, mining or petroleum drilling operations must be located where the mineral resource is available. The decision in this case is simply whether to locate or not to locate at the source.

We now deal with some of the well known quantitative and semi-quantitative techniques of plant location.

(A) **Composite Measure Method.** The basic steps of this method are listed below sequence-wise.

(*i*) Develop a list of all relevant factors.

(*ii*) Assign a scale to each factor and designate some minimum.

(*iii*) Weigh the factors relative to each other in light of importance towards achievement of system goals.

(*iv*) Score each potential location according to the designated scale and multiply the score by the weights.

(*v*) Total the points for each location and either use them in conjunction with a separate economic analysis or include an economic factor in the list of factors and choose the location on the basis of maximum score.

The following example will illustrate the application.

Example 1. There are three potential sites and five relevant factors like transportation costs per week, labour costs per week, finishing material supply, maintenance facilities and community attitude. The costs are in rupees whereas for the last three factors, points are assigned on 0–100 scale. The data are given below :

Table 2.2. Payoff Matrixs

Factors		***Potential Location Sites***		
		S_1	S_2	S_3
(1) Transportation cost/week (Rs.)	F_1	**800**	**640**	**500**
(2) Labour cost/week (Rs.)	F_2	**1180**	**1020**	**1160**
(3) Finishing material supply	F_3	**30**	**80**	**70**
(4) Maintenance facilities	F_4	**60**	**20**	**30**
(5) Community attitude	F_5	**50**	**80**	**70**

The location analyst has pre-established weights for various factors. This includes a standard of 1.0 for each Rs. 10 a week of economic advantage. Other weights applicable are 2.0 on finishing material supply, 0.5 on maintenance facilities and 2.5 on community attitude. Also the organisation prescribes a minimum acceptable score of 30 for maintenance facilities. Select a suitable site based on the above given data.

[IGNOU (MS5) 1998]

Solution. Let us consider the first 2 factors first.

Table 2.3

	S_1	S_2	S_3
$F_1 + F_2 =$	Rs. 1980	1660	1740
Economic Advantage :	0	$1980 - 1660 = 320$ (S_2 over S_1)	$1980 - 1740 = 240$ (S_3 over S_1)
Monetary value converted to points :	0	$\frac{320}{10} \times 1 = 32$	$\frac{240}{10} \times 1 = 24$

Now we prepare the decision matrix table next.

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Table 2.4. Decision Matrix.

Factors	*Weightage*	S_1	S_2	S_3
Combined (F_1 + F_2) economic advantage	1.0	0	32	24
F_3 (finishing material supply)	2.0	30	80	70
F_4 (Maintenance facilities)	0.5	60	20	30
F_5 (Community attitude)	2.5	50	80	70
Composite site rating		1.0 × 0 + 2.0 × 30 + 0.5 × 60 + 2.5 × 50 = 215	1.0 × 32 + 2.0 × 80 + 0.5 × 20 + 2.5 × 80 = 402	1.0 × 24 + 2.0 × 70 + 0.5 × 30 + 2.5 × 70 = 354

The maximum score of 402 is achieved by site S_2 in the decision matrix table and so S_2 may be an obvious selection of the preferred site. But it does not satisfy the minimum acceptable score of 30 for maintenance facilities and so it is discarded and the next best score of 354 of site S_3 is taken into consideration and S_3 is adjudged as the preferred site.

(*B*) **Locational Breakeven Analysis.** Sometimes it is useful to draw location breakeven chart which could aid in deciding which location would be optimal. The following example will show you 'how'.

Example 2. A manufacturer of automobile carburetors is considering three locations *P*, *Q* and *R* for a new plant. Cost studies indicate that fixed costs per year at the sites are Rs. 30,000, Rs. 60,000 and Rs. 110,000 respectively; and variable costs are Rs. 75 per unit, Rs. 45 per unit and Rs. 25 per unit respectively. The expected selling price of the carburetors produced is Rs. 120. The company wishes to find the most economical location for an expected volume of 2000 units per year.

[IGNOU (MS5) June 2000, IMT Ghaziabad 1999, Jabalpur B.E. (Mech.) 1992]

Solution. For each of the three locations the fixed cost points and total cost (fixed cost + variable cost) lines have been shown in the breakeven chart shown in Fig. 1.1.

$y = c + mx$

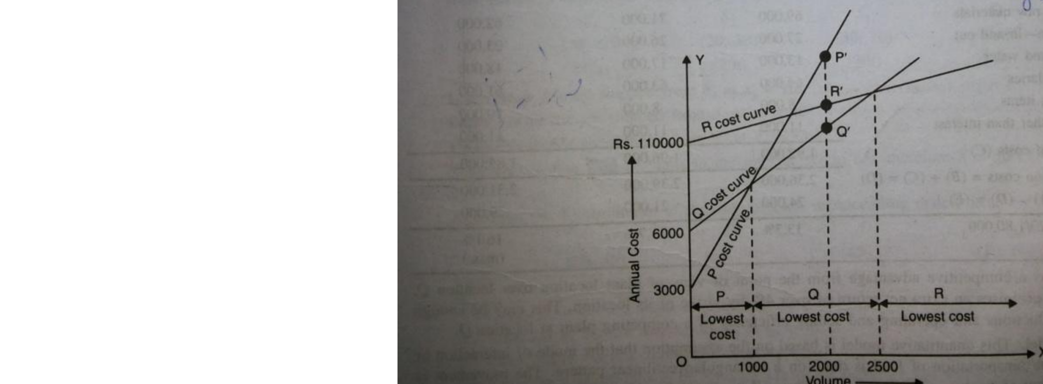

Fig. 2.1. Breakeven Chart.

PLANT LAYOUT
STUDY MATERIAL FROM BOOK 2

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3

Chapter

Locational Economics and Plant Layout

"The Locational Economics is concerned with the selection of location for an industrial complex. It is of supreme importance as 4 M's are brought together here for manufacturing purposes. Plant layout is the physical arrangement of industrial facilities within the plant so that each operation is performed at the point of greatest convenience."

INSIDE THIS CHAPTER

3.1 Importance of Plant Location
3.2 Plant Location
3.3 Factors Affecting Plant Location
3.4 Plant Layout
3.5 Analytical Tools/Procedure of Plant Layout

3.1 IMPORTANCE OF PLANT LOCATION

The selection of location is an important activity as far as the success of a business is concerned and thus it requires careful analysis. This selection is of prime importance both for new as well as established/existing enterprises.

The fundamental objective of an enterprise is to maximise its profit which can be achieved either by increasing sales value or by reducing the cost of production. So the choice of location is vital for any new enterprise for its success. The organisation can have better and upto date understanding of the market conditions and thus can formulate more effective production and marketing strategies for increasing sales if the firm is located near its potential market. The reduction in cost of production is possible if the enterprise is located at a place where all types of production economies with respect to input factors are available. If the selected site of the plant is unfavourable, the business cannot be managed economically and profitably. Thus the survival as well as prosperity of a business unit depends to a large extent on its location.

3.2 PLANT LOCATION

The need to secure advantageous location for any type of industrial complex is of supreme importance since a plant is a place where Men, Machines, Materials and Methods etc. are brought together for manufacturing product. The problem of plant location arises while starting a new plant or during the expansion of the existing unit. ·

Plant location means deciding a suitable location, place, area etc. where the unit or factory shall start functioning. The site of a plant has a big role to play in the success or failure of a plant. Since a wrong location may result in low profit margin, high cost of production, low productivity, high distribution cost and labour problem etc. Plant location deals with two activities. First, selection of a proper geographical area or general territory, second, selecting a particular site within that region.

3.3 FACTORS AFFECTING PLANT LOCATION

Hardly any site of a plant can be ideal or perfect. The criteria for plant location is to minimize the over all cost affected by location. One has to strike a balance between opposing factors affecting plant location which are discussed as follows:

3.3.1 Selection of Region

The selection of a region or area in which plant is to be installed requires the consideration of the following:

3.3.1.1 Availability of Raw Materials

Proximity of sources of raw materials is the obvious explanation of the location of majority of sugar mills in Uttar Pradesh. This means that the raw material should be available within the economical distance. Easy availability of supplies required for maintenance and operation of the plant should also be considered.

3.3.1.2 Proximity to Markets

Cost of distribution is an important item in the overhead expenses. So it will be advantageous to be near to the centre of demand for finished products. Importance of this is fully realized if the material required for the manufacturing of products are not bulk and freight charges are small. Consumer industries like cycles, sewing machines, radio, televisions and other luxury goods etc. are set up near the marketing centres whereas producer industries like steel mills are located near the vicinity of raw materials.

For this purpose market analysis should be carried out keeping in view the following points:

(*a*) Market trend and competition regarding product to be manufactured.
(*b*) Industrial market.
(*c*) Consumer habits and income.
(*d*) Population.
(*e*) Scope of export to neighbouring countries.

3.3.1.3 Transport Facilities

Since freight charges of raw materials and finished goods enter into the cost of production, therefore transportation facilities are becoming the governing factor in economic location of the plant. Depending upon the volume of the raw materials and finished products, a suitable method of transportation like rail, road, water transportation (through river, canals or sea) and air transport is selected and accordingly plant location is decided. Important consideration should be that the cost of transportation should remain fairly small in comparison to the total cost of production.

3.3.1.4 Availability of Power, Fuel or Gas

Because of the widespread use of electrical power the availability of fuel or gas has not remained a deciding factor in most of the cases for plant location. The location of thermal power plants (like Bokaro Thermal Plant) and steel plants near coal fields are for cutting down cost of the fuel transportation. The reliability of continuous supply of these facilities is an important factor.

3.3.1.5 Water Supply

Water is required for processing as in chemical, sugar and paper industries and is also used for drinking and sanitary purposes. Investigation for quality and probable source of supply is important. Since the cost of treating water is substantial so the chemical properties like hardness, alkalinity, acidity, presence of dissolved gases and organic material etc. should be thoroughly investigated.

In case of water supply from an external source such as municipality, dependability of the source, pumping and storage capacity for present and future demands should be found out.

3.3.1.6 Disposal Facility for Waste Products

Thorough study should be made regarding disposal of water like effluents, solids, chemicals and other waste products likely to be produced during the production process.

3.3.1.7 Climatic and Atmospheric Conditions

The climate of the region/area where the plant is to be located has an important bearing on both the capital and operational costs. Normally following aspects are considered:

(*a*) Rain fall or snow fall in the area concerned.
(*b*) Ambient temperatures.
(*c*) Humidity.
(*d*) Wind velocities and direction.
(*e*) Incidence of cyclones, storms etc.

3.3.1.8 Availability of Labour

Potential supply of requisite type of labour governs plant location to a major extent. Some industries need highly skilled labour while others need unskilled and intelligent labour. But the former type is difficult in rural areas in comparison with industrially developed locations.

3.3.1.9 Momentum of an Established Industry

Already established industry in a certain area will produce skilled labour in that trade. Thus future industries in that area will have no difficulty with respect to the skilled labour e.g. Ludhiana is famous for cycle industries and Faridabad for Engineering industries.

3.3.1.10 Preference of Outstanding Businessmen and Government Subsidies

Some of the factory locations do not consider the above factors but locate industries in a particular district or area just to develop that area. It may be due to State Government policies regarding workers, pollution and smoke control requirements, waste disposal rules for industries etc.

3.3.2 Township Selection

The factors to be considered regarding township selection are:

(*i*) Availability of man power of requisite skill.
(*ii*) Competitive wage rates of workers.
(*iii*) Other enterprises which are complementary or supplementary regarding raw materials, other input, labour and skills required.
(*iv*) Moderate taxes and the absence of restricting laws.
(*v*) A favourable cooperative and friendly attitude towards the industry.
(*vi*) Favourable living conditions and standards keeping in view the availability of medical and educational facilities, housing, fire service, recreational facilities, cost of living etc.

3.3.3 Question of Urban and Rural Area

Question of urban and rural area should also be decided in view of the following:

3.3.3.1 Advantages of Rural Area

(*i*) The initial cost of land, erection cost of building and plant is less in rural area as compared to urban or city area.

(ii) Acquisition for additional area for extension work expansion of plant is possible without much difficulty whereas urban area being congested, the additional land is not easily available.

(iii) Rural areas are free from labour trouble which are most common in towns and cities.

(iv) Over crowding of working class population in cities is avoided.

3.3.3.2 Advantages of Urban Area

(i) Better modes of transportation for collection and distribution of materials and finished products.

(ii) Availability of requisite type of labour for special and specific jobs is there.

(iii) Utilities like water, power, fuels etc. are easily available.

(iv) Industries do not need to construct colonies to provide residential facilities to their workers since houses are available on rental basis whereas in rural areas houses have to be build for workers.

3.3.4 Location of a Factory in a Big City

Generally factories are located in big cities for obvious reasons of skilled labour, close market proximity for both raw materials and end products. Its advantages and disadvantages are mentioned below:

3.3.4.1 Advantages

(i) Existence of educational and recreational facilities is advantageous for children and dependants of workers.

(ii) Facilities for technical/industrial education and training for children of workers are available.

(iii) Evening classes facilities are available.

(iv) Discussion opportunities and facilities for exchange of thought are available for interested people in societies and clubs.

(v) All types of skilled man power is available.

(vi) Repair, maintenance and service facilities for various utilities are available in abundance.

(vii) Banking facilities regarding finance (loan etc.) for industry in case of necessity are available.

(viii) Big markets for sale of products available.

(ix) Better transport facilities for movement of raw materials, finished products and workers are available.

(x) Many similar industries/plants exist in nearby areas.

(xi) Housing facilities workers & employees.

(xii) Police and fire protection facilities available in near by area.

3.3.4.2 Disadvantages

(i) Insurance and taxation rate are high.

(ii) Due to higher living standards, cost of consumer goods and wage rates are high.

(iii) Possibilities of expansion are minimum due to scarcity of land.

(iv) Cost of land is more if needed for expansion of the plant etc.

(v) Building costs very high in comparison to rural or semiurban areas.

(vi) Atmospheric conditions not very pleasant rather suffocating.

(vii) Local bye laws present a problem for future, working & expansion etc.

Thus small plants may find location in big cities that too in upper stories of the buildings. Such accommodation may be utilized in view of availability of requisite type of labour in big cities.

3.3.5 Location of an Industry in Small Town

There are some industries which are located in the rural areas or small towns specifically for the want of raw material and cheap labour. Its advantages and disadvantages are mentioned below:

3.3.5.1 Advantages

(i) Less labour trouble and co-ordinal employee-employer relations.
(ii) Suitable land for current and future requirements easily available.
(iii) Local bye laws do not impose problem in working of the unit.
(iv) No resistance from existing industries.
(v) Possibility of tax exemptions exist.
(vi) Not much congestion.
(vii) Lower rents in comparison to big cities and urban areas.
(viii) Lower wage rates for labour/employees/workers.
(ix) Less fire risks.
(x) Noise not much problem.

3.3.5.2 Disadvantages

(i) Scarcity of skilled labour of requisite type.
(ii) Lack of recreational and amusement facilities for staff.
(iii) Facilities like evening classes and industrial training do not exist.
(iv) Employees/workers do not get accustomed to factory life easily.
(v) Specialized services needed for various purposes are not available.
(vi) Police and fire protection less satisfactory.
(vii) Transportation and marketing facilities not satisfactory as required.

3.3.6 The Sub-urban Location for a Factory

Such a location generally provides advantages of both the large city and small towns. Benefits of such a locality may be summarized as follows:

(i) Land is easily and cheaply available in comparison to big cities.
(ii) Lower tax rates in comparison to big cities and urban areas.
(iii) Transportation facilities equal to big cities available.
(iv) Good living accommodation to enjoy advantages of big cities available for workers/employees.
(v) Unskilled labour cheaply available.
(vi) Recreational facilities of cities available due to easy transport facilities.

3.3.7 Site Selection

The third step is to select the exact plant site with the following considerations:

(i) The cheap availability of land for current and future requirements, soil characteristics sub soil water, availability or possibility of economic drainage and waste disposal system are desirable parameters.
(ii) The site should be easily accessible to various modes of transport as required so that apart from input materials, employees can also reach the site conveniently.
(iii) The site should be free from zonal restrictions like from railways or civil aviation restrictions.

3.3.8 Current Trends in Plant Location

3.3.8.1 Location in Proximity of Cities

First tendency is to locate the industries or enterprises in the proximity of cities rather than in rural or urban areas. These sub-urban sites offer today practically all advantages, facilities and services available in cities and towns with the added advantage of land required for future expansion on cheap rates.

3.3.8.2 Planned Industrial Centres

While industrial towns may be planned and developed by big industrial houses or govt., the latest trend is to develop areas as industrial estates and sell these to people interested in starting their units at various places. Noida and Faridabad are the examples of this type of development.

3.3.8.3 Competition for Development of Industries

In order to generate the employment opportunities the state and central govt. offer concessions to attract industrialists to set up industries in their states or territories.

3.3.9 Appropriate Site Selection

Appropriate site selection is important because of the following:

(*i*) A good location may minimize the cost of production and distribution to a considerable extent. Such reduction in the cost of production helps in elevating either the competitive strength or the profit margin of the business.

(*ii*) Initiation of an enterprise involve a relatively large permanent investment. If the selected site is not proper, all the money invested on factory building, installation of machinery etc. will go as waste and the owner will have to suffer a great loss.

(*iii*) Location put constraints for the physical factors of the overail plant designes heating, ventilation requirements, storage capacity for raw materials, transportation requirements for input materials and finished products, energy requirements cost of labour, taxes and construction costs.

(*iv*) Location of plant decides the nature of investment cost to be incurred.

(*v*) Government policies sometimes play an important role in site selection.

(*iv*) Probably no location is so perfect as to guarantee success but locations can be so bad as to bankrupt an enterprise.

A comparision of rural and urban areas regarding site selection for an industry is given in Table 3.1.

3.3.10 The Design of Factory Plant Building

After a plant location has been decided upon, management's next problem deals with the design of building. A building is designed and built to protect the property and employees of an organization. This basic fact is mostly overlooked in planning the requirement for building structures. For those plants where employees, materials and infrastructural facilities require protection, the problems involved in designing and constructing effective and economical structures are many. Good building design and planning can reduce manufacturing cost due to following reasons:

1. Reduction of work-in process inventory.
2. Lowering down material handling cost.
3. Reducing storage costs.
4. Reducing the manufacturing cycle time.
5. Simplifying manufacturing and employees control procedure.
6. Reducing plant repair & maintenance costs.
7. Decreasing work stoppage and interruptions during production cycle.
8. Increasing plant flexibility and utilization.
9. Reducing employee hiring and training cost.
10. Increasing morale of workers and reducing employee turnover.

Practically in all industrial situations, plants or building is composed of rectangular or square areas. The combinations result commonly in building of the shape L, T, U, G, H, F, E, I, O and polygonal. Generally speaking a square building is cheaper to construct than a rectangular building because the square will have less perimeter per square metre of usable area. This reduction in perimeter length results in lower foundation and outside site and boundary wall costs. At the same time however the square shape of the building normally does not suit to efficient production or assembly lines patterns. Furthermore, the cost of structural steel for floor and roof supports in the square building will likely to exceed that for a rectangular building and may offset the possible savings in foundation and wall costs.

TABLE 3.1: Comparison of Rural and Urban Areas Regarding Site Selection for and Industry

	Urban	*Rural*
1.	Labour availability—diversified type of labour is available.	Difficult to get requisite skilled labour.
2.	Local demand for the product is fairly high due to large population.	Market place is far away from the enterprise so cost of distribution of finished product is more.
3.	Good transportation facilities are available.	Requisite transportation facilities are not available
4.	In proximity of allied industries.	Away from allied units.
5.	Education, recreational health and other social facilities are available.	Absence of educational, recreational social and health facilities.
6.	Sufficient land is not available even at higher rates.	Sufficient land is available at cheaper rates.
7.	There are many restrictions on factory building construction.	No restrictions on building construction.
8.	Certain facilities and public utility services such as water supply drainage and fire fighting etc. are available.	These facilities and public utility service are not available.
9.	Prompt postal and communication services are available.	Prompt postal and telephone services are not available.
10.	Tax rates are high.	Taxes are quite low.
11.	Labour cost is relatively high.	Labour is available at cheap rates.
12.	Banking and insurance facilities are available.	Insurance and banking facilities are not available.
13.	Labour force is not stable due to large number of industries.	Labour force is stable.
14.	Trade unions are more active which sometimes results in strikes and lock outs.	Trade movements are not set.
15.	Training facilities for workers and management institutes for executives put the urban areas in privileged position.	Training facilities and management institutes are not available for workers and executies.
16.	Requisite storage facilities including warehouses are available.	Storage facilities like warehouses are not available.
17.	Concentration of industries in urban areas creats air and water pollution problems.	Problems of air and water pollution are less.
18.	To stop concentration of industries, Govt. imposes restrictions for starting new industrial units in urban areas.	Govt. provides facilities like financial assistance, land at cheaper rates to start new industries in rural areas.

Most industrial building can be categorised into three groups as mentioned below:

3.3.10.1 Single Storey Building

The trend today is toward the construction of single storey buildings particularly where land is available at a reasonable price. Following are the advantages offered by single storey building:

(*i*) It provides the cheapest overall cost per square metre of operating space of the plant.
(*ii*) It is easily and quickly constructed.
(*iii*) Greater flexibility in layout of the plant possible.

(iv) Truss construction makes for unimpaired operating space.
(v) Minimum vibrations from floors being on the ground.
(vi) Ease of ventilation, heating and air conditioning of the space.
(vii) Elimination of costs and maintenance of stairways.
(viii) Easy to expand by removing walls.
(ix) All equipment is on the same level, providing easier, more effective layout and control.
(x) Unrestricted floor load capacities available.
(xi) Supervision on one floor easy.

Following are the limitations of single storey buildings:

(i) Cost of heating and ventilation is more.
(ii) Roof maintenance cost is higher.
(iii) Longer ground runs for drainage required.
(iv) Water storage less convenient.
(v) Maintenance of glasses and lights is expensive affair.

Single storey building's roof structure are of the following four types:

(i) Flat
(ii) Gable
(iii) Sawtooth
(iv) Bow string

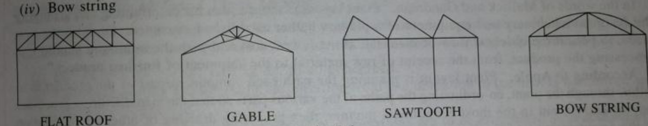


Fig. 3.1

3.3.10.2 Highbay and Monitar Type Buildings

These types of single storey buildings are designed to give maximum overhead space for a given floor space. If properly designed and constructed almost all the vertical walls can have windows for natural illumination.

The monitor type building is usually found in companies requiring good natural ventilation and considerable overhead room for operating cranes and other overhead facilities. Buildings for foundries and steel mills are often of the monitor or highbay type enabling the firms to take advantage of the natural ventilation resulting from the high roof.

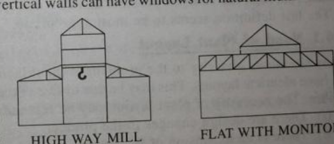


Fig. 3.2

3.3.10.3 Multistorey Building

Following are the advantage of multistorey buildings:

(i) Less roof repairs.
(ii) Heating and ventilation cost less.
(iii) Small ground runs for drainage.
(iv) More compact layout.
(v) Provides for maximum operating floor space per square metre of land.
(vi) Easily adopted for the manufacture of light goods.

Following are the limitations of multistorey buildings:

(*i*) These present problems in heavy goods industries.
(*ii*) Material handling can be relatively expensive for bulky materials because of the vertical transfer between floors.
(*iii*) Natural illumination in the centre of a multistorey building is often poor.
(*iv*) Flexibility is hampered in multistorey buildings because changes in the width and length of a floor are usually impossible except at ground level.

3.4 PLANT LAYOUT

Meaning and Definition of Plant Layout: Plant layout is the most effective physical arrangement, either existing or in plans of industrial facilities i.e arrangement of machines, processing equipment and service departments to achieve greatest co-ordination and efficiency of 4M's (Men, Materials, Machines and Methods) in a plant. Layout problems are fundamental to every type of organisation/enterprise and are experienced in all kinds of concerns/undertakings. The adequacy of layout affects the efficiency of subsequent operations. It is an important pre-requisite for efficient operations and also has a great deal in common with many problems. Once the site of the plant has been decided, the next important problem before the management of the enterprise is to plan suitable layout for the plant.

Definitions: According to James Lundy, "Layout identically involves the allocation of space and the arrangement of equipment in such a manner that over all operating costs are minimized."

In the words of Mallick and Gandreau, "Plant layout is a floor plan for determining and arranging the designed machinery and equipment of a plant, whether established or contemplated, in the best place, to permit the quickest flow of material, at the lowest cost and with the minimum handling in processing the product, from the receipt of raw material to the shipment of finished product."

According to Apple, "Plant layout is planning the path each component/part of the product is to follow through the plant, co-ordinating the paths of the various parts so that the manufacturing processes may be carried out in the most economical manner, then preparing drawing or other representation of the arrangement and finally seeing that the plan is properly put into effect." (Plant Layout and Material Handling by Apple)

In the words of Sansonneti and Mallick (Factory Management, Vol. 103) "It is placing the right equipment, coupled with right place, to permit the processing of a product unit in the most effective manner, through the shortest possible distance and in the shortest possible time."

The last definition seems to be most appropriate.

3.4.1 Need of Plant Layout

Many situations give rise to the problem of plant layout. Two plants having similar operations may not have identical layouts. This may be due to size of the plant, nature of the process and management's calibre. The necessity of plant layout may be felt and the problem may arise when:

(*i*) There are design changes in the product.
(*ii*) There is an expansion of the enterprise.
(*iii*) There is proposed variation in the size of the departments.
(*iv*) Some new produet is to be added to the existing line.
(*v*) Some new department is to be added to the enterprise and there is reallocation of the existing department.
(*vi*) A new plant is to be set up.

3.4.2 Importance of Plant Layout

The layout of a plant is quite important in view of the above definition but the importance of a layout may greatly vary from industry to industry. The possibility of attaining the best possible layout is directly proportional to following factors:

3.4.2.1 *The Weight, Volume or Mobility of the Product*

If the final product is quite heavy or difficult to handle involving costly material handling equipment or a large amount of labour, important consideration will be to move the product minimum possible e.g. boiler, turbines, locomotive industries and ship building companies etc.

3.4.2.2 *Complexity of the Final Product*

If the product is made up of a very large number of components and parts i.e. large number of people may be employed for handling the movement of these parts from shop to shop or from machine to machine or one assembly point to another e.g. automobile industry.

3.4.2.3 *The Length of the Process in Relation to Handling Time*

If the material handling time represents a appreciable proportion of the total time of manufacturing, any reduction in handling time of the product may result in great productivity improvement of the industrial unit e.g. Steam Turbine Industry.

3.4.2.4 *The Extent to which the Process Tends towards Mass Production*

With the use of automatic machines in industries for adopting mass production system of manufacturing the volume of production will increase. In view of high production output, larger percentage of manual labour will be engaged in transporting the output unless the layout is good.

3.4.3 Objectives of Good Plant Layout

A good rather an optimum layout is one which provides maximum satisfaction to all concerned i.e. shareholders, management employees and consumers. The objectives of a good layout are a follows:

(*i*) Should provide overall satisfaction to all concerned.
(*ii*) Material handling and internal transportation from one operation to the next is minimized and efficiently controlled.
(*iii*) The production bottle necks and points of congestions are to be eliminated so that input raw materials and semi-finished parts move fast from one work station to another.
(*iv*) Should provide high work in process turnover.
(*v*) Should utilize the space most effectively; may be cubical utilization.
(*vi*) Should provide worker's convenience, promote job satisfaction and safety for them.
(*vii*) Should avoid unnecessary investment of capital.
(*viii*) Should help in effective utilization of labour.
(*ix*) Should lead to increased productivity and better quality of the product with reduced capital cost.
(*x*) Should provide easy supervision.
(*xi*) Should provide space for future expansion of the plant.
(*xii*) Should provide proper lighting and ventilation of the areas of work stations

3.4.4 Principles of Plant Layout

According to Muther there are six basic principles of "best layout". These are:

3.4.4.1 *Principle of Overall Integration*

According to this principle the best layout is one which provides integration of production facilities like men, machinery, raw materials, supporting activities and any other such factors which result in the best compromise.

3.4.4.2 *Principle of Minimum Distance*

According to this principle the movements of men and materials should be minimized.

3.4.4.3 Principle of Flow

According to Muther, the best layout is one which arranges the work station for each operation/process in same order or sequence that forms treats or assembles the materials.

3.4.4.4 Principle of Cubic Space Utilization

According to this, the best layout utilizes cubic space i.e. space available both in vertical and horizontal directions is most economically and effectively utilized.

3.4.4.5 Principle of Satisfaction and Safety

According to this principle best layout is one which provides satisfaction and safety to all workers concerned.

3.4.4.6 Principle of Flexibility

In automotive and other allied industries where models of products change after sometime the principle of flexibility provides adoption and rearrangement at a minimum cost and least inconvenience.

3.4.5 Factors Affecting Plant Layout

Whatever be the type of layout being contemplated the following factors are to be considered because these factors have got significant influence on the design of the layout.

3.4.5.1 Man Factor

The man is very flexible element who can be made suitable for all sort of layouts. Main considerations are as follows:

(*i*) Safety and working conditions.
(*ii*) Man power requirements-skill level of workers, their number required and their training programme.
(*iii*) Man power utilization in the plant.
(*iv*) Human relations.

3.4.5.2 Material Factor

It includes the various input materials like raw materials, semi-finished parts, materials in process scrap, finished products, packing materials, tools and other services. The main considerations are:

(*i*) Design and specifications of the product to be manufactured.
(*ii*) Quantity and variety of products and materials.
(*iii*) Physical and chemical characteristics of various inputs materials.
(*iv*) Component parts or material and their sequence of operations i.e. how they go together to generate the final product.

3.4.5.3 Machinery Factor

The operating machinery is also one of the most important factors therefore all the informations regarding equipment and the tools are necessary for inspection, processing and maintenance etc.

(*i*) The processes and methods should be standardized first.
(*ii*) Machinery and tools selections depend upon the type of process and method, so proper machinery and other supporting equipment should be selected on the basis of volume of production.
(*iii*) Equipment utilization depends on the variation in production, requirements and operating balance. Machines should be used to their optimum levels of speed, feed and depth of cut.
(*iv*) Machinery requirement is mostly based on the process/method.
(*v*) Maintenance of machines and replacement of parts is also important.

3.4.5.4 Movement Factor

It mainly deals with the movement of men and materials. A good layout should ensure short moves and should always tend towards completion of product. It also includes interdepartmental movements and material handling equipment. This includes the flow pattern reduction of unnecessary handling, space for movement and analysis of handling methods.

3.4.5.5 Waiting Factor

Whenever material or men is stopped, waiting occurs which costs money. Waiting cost includes handling cost in waiting area, money tied up with idle material etc.

Waiting may occur at the receiving point, materials in process, between the operations etc. The important considerations in this case are:

(*a*) Location of storage or delay points.
(*b*) Method of storing.
(*c*) Space for waiting.
(*d*) Safeguard equipment for storing and avoiding delay.

3.4.5.6 Service Factor

It includes the activities and facilities for personnel such as fire protection, lighting, heating and ventilation etc. Services for material such as quality control, production control, services for machinery such as repair and maintenance and utilities like power, fuel/gas and water supply etc.

3.4.5.7 Building Factor

It includes outside and inside building features, shape of building, type of building (single or multistorey) etc.

3.4.5.8 Flexibility Factor

This includes consideration due to changes in material, machinery, process, man, supporting activities and installation limitations etc. It means easy changing to new arrangements or it includes flexibility and expendability of layouts.

3.4.6 Advantages of a Good Plant Layout

The advantages expressed by Mallick and Gandeau are as follows:

3.4.6.1 To the Worker

(*i*) Reduces the effort of the worker.
(*ii*) Reduces the number of handlings.
(*iii*) Extends the process of specialization.
(*iv*) Permits working at optimum conditions by eliminating congestions.
(*v*) Produces better working conditions by eliminating congestions.
(*vi*) Reduces the number of accidents.
(*vii*) Provides better employee service facilities/conditions.
(*viii*) Provides basis for higher earning for employees.

3.4.6.2 In Labour Cost

(*i*) Increases the output per man-hour.
(*ii*) Reduces set up time involved.
(*iii*) Reduces the number of operations or some operations may be combined.
(*iv*) Reduces the number of handlers. Thus reducing labour cost.
(*v*) Reduces the length of hauls.
(*vi*) Reduces lost motions between operations.
(*vii*) Converts operator into a producer instead of a handler by eliminating the various unnecessary movements.

3.4.6.3 In Other Manufacturing Costs

(*i*) Reduces the cost of expensive supplies.
(*ii*) Decreases maintenance costs.
(*iii*) Decreases tool replacement costs.
(*iv*) Effects a saving in power loads.
(*v*) Decreases spoilage and scrap. Thus waste is minimized
(*vi*) Eliminates some of the waste in raw material consumption.
(*vii*) Improves the quality of the product by decreasing handling.
(*viii*) Provides better cost control.

3.4.6.4 In the Manufacturing Cycle

(*i*) Shortens the moves between work-stations.
(*ii*) Reduces the manufacturing cycle in each department.
(*iii*) Reduces the length of the travel by the product for completion.
(*iv*) Reduces the overall time of manufacturing the product.

3.4.6.5 In Production Control

(*i*) Facilitates receipts, shipments and delivery of inputs and finished goods.
(*ii*) Provides adequate and convenient storage facilities.
(*iii*) Permits the maximum possible output with same input.
(*iv*) Paces production & determines production flow.
(*v*) Makes production time predictable.
(*vi*) Makes scheduling and dispatching automatic.
(*vii*) Sets up production centre & permits straight line layout by products for mass production.
(*viii*) Permits layout by process for job order manufacturing.
(*ix*) Moves work in process by most direct lines.
(*x*) Reduces the number of lost or mishandled parts leading to waste minimization.
(*xi*) Reduces the paper work for production control & reduces the number of stock chasers. Thus reduces production control expenses.

3.4.6.6 In Supervision

(*i*) Tends to ease the burden of supervision.
(*ii*) Determines the supervisory control.
(*iii*) Reduces the cost of supervision process.
(*iv*) Reduces cost of piece counts.
(*v*) Decreases the amount of inspection involved.

3.4.6.7 In Capital Investment

(*i*) Holds permanent investment at its minimum level.
(*ii*) Keeps the plant from becoming obsolete before it is worn out.
(*iii*) Reduces the investment in machinery and equipment by
  (*a*) Increasing the production per machine.
  (*b*) Utilizing idle machine time.
  (*c*) Reducing the number of operations per machine.
(*iv*) Maintains a proper balance of departments.
(*v*) Eliminates wasted aisle space.
(*vi*) Reduces the capital investment by proper space utilization of material handling equipment required.
(*vii*) Reduces the inventory level of work in process and of finished product.

3.4.7 Types of Layout

Production results from men, materials and machinery together with management. The characteristics are changed. To manufacture a product layout begins with which element or elements mentioned above move. Keeping in view the type of industry and volume of production, the type of layout to be selected is to be decided from the following:

1. Product or Line Layout.
2. Process or Functional Layout.
3. Fixed Position Layout.
4. Combination type of Layout.

3.4.7.1 Product or Line Layout

If all the processing equipment and machines are arranged according to the sequence of operations of a product, the layout is called product type of layout. In this type of layout, only one product or one type of products is produced in an operating area. This product must be standardized and produced in large quantities in order to justify the product layout. The raw material is supplied at one end of the line and goes from one operation to the next quite rapidly with a minimum work in process, storage and material handling. Fig. 3.3 shows product layout for two types of products A and B.

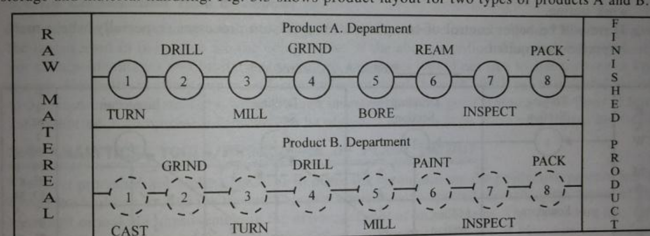


Fig. 3.3

Advantages offered by Product Layout

(*i*) Lowers total material handling cost.
(*ii*) There is less work in process.
(*iii*) Better utilization of men and machines.
(*iv*) Less floor area is occupied by material in transit and for temporary storages.
(*v*) Greater simplicity of production control.
(*vi*) Total production time is also minimized.

Limitations of Product Layout

(*i*) No flexibility which is generally required is obtained in this layout.
(*ii*) The manufacturing cost increases with a fall in volume of production.
(*iii*) If one or two lines are running light, there is a considerable machine idleness.
(*iv*) A single machine breakdown may shut down the whole production line.
(*v*) Specialized and strict supervision is essential.

3.4.7.2 Process or Functional Layout

The process layout is particularly useful where low volume of production is needed. If the products are not standardized, the process layout is more desirable, because it has greater process flexibility than other. In this type of layout the machines are not arranged according to the sequence of operations but are arranged according to the nature or type of the operations. This layout is commonly suitable for non repetitive jobs. Same type of operation facilities are grouped together such as lathes will be placed at one place, all the drill machines are at another place and so on. See Fig. 3.4 for process layout. Therefore, the process carried out in any area is according to the machine available in that area.

Advantages of Process Layout

(*i*) There will be less duplication of machines. Thus total investment in equipment purchase will be reduced.
(*ii*) It offers better and more efficient supervision through specialization at various levels.
(*iii*) There is a greater flexibility in equipment and man power thus load distribution is easily controlled.
(*iv*) Better utilization of equipment available is possible.
(*v*) Breakdown of equipment can be easily handled by transferring work to another machine/work station.
(*vi*) There will be better control of complicated or precision processes, especially where much inspection is required.

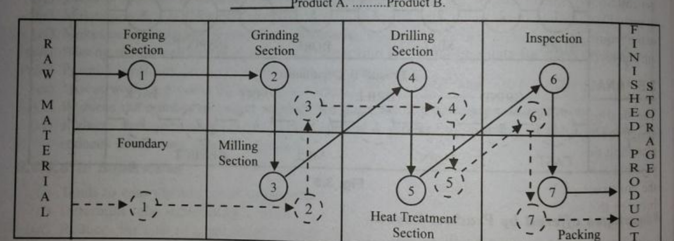


Fig. 3.4

Limitations of Process Layout

(*i*) There are long material flow lines and hence the expensive handling is required.
(*ii*) Total production cycle time is more owing to long distances and waiting at various points.
(*iii*) Since more work is in queue and waiting for further operation hence bottlenecks occur.
(*iv*) Generally more floor area is required.
(*v*) Since work does not flow through definite lines, counting and scheduling is more tedious.
(*vi*) Specialization creates monotony and there will be difficulty for the laid workers to find job in other industries.

3.4.7.3 Fixed Position Layout

This type of layout is the least important for today's manufacturing industries. In this type of layout the major component remain in a fixed location, other materials, parts, tools, machinery, manpower and other supporting equipment are brought to this location. The major component or body of the product remains in a fixed position because it is too heavy or too big and as such it is economical and convenient to bring the necessary tools and equipments to work place alongwith the man power. This type of layout is used in the manufacture of boilers, hydraulic and steam turbines and ships etc.

Advantages Offered by Fixed Position Layout

(*i*) Material movement is reduced
(*ii*) Capital investment is minimized
(*iii*) The task is usually done by gang of operators, hence continuity of operations is ensured
(*iv*) Production centres are independent of each other. Hence effective planning and loading can be made. Thus total production cost will be reduced
(*v*) It offers greater flexibility and allows change in product design, product mix and production volume.

Limitations of Fixed Position Layout

(*i*) Highly skilled man power is required.
(*ii*) Movement of machines equipments to production centre may be time consuming.
(*iii*) Complicated fixtures may be required for positioning of jobs and tools. This may increase the cost of production.

3.4.7.4 Combination Type of Layout

Now a days in pure state any one form of layouts discussed above is rarely found. Therefore generally the layout used in industries are the compromise of the above mentioned layouts. Every layout has got certain advantages and limitations therefore, industries would not like to use any type of layout as such. Flexibility is a very important factor, so layout should be such which can be moulded according to the requirements of industry, without much investment. If the good features of all types of layouts are connected, a compromise solution can be obtained which will be more economical and flexible.

3.5 ANALYTICAL TOOLS/PROCEDURE OF PLANT LAYOUT

The ideal procedure for a plant layout is to make the layout around the productive process and then design the building around the layout. This procedure may be applied for making the layout of a new plant/unit or making improvement in the existing layout of an enterprise. This procedure may not be possible always because of the existence of plant building or the shape of plant site may not allow the construction of building around the productive process etc. Thus one has to strike a balance between the two approaches.

For an efficient layout the following basic information is needed for further planning:

(*i*) Dimensional plan of the space to be used for layout.
(*ii*) Product specifications and bill of materials.
(*iii*) Value and rate of production.
(*iv*) Description of the operations, their sequence and standard times in production process.
(*v*) The equipment and machinery required to perform operations.
(*vi*) Work force size and type (skill).
(*vii*) Material holding system to be used.
(*viii*) Amount of material, buffer stock required at each work station.
(*ix*) Size of finished and semifinished inventory.
(*x*) Type of communications and fire fighting equipment required for the plant.
(*xi*) Special requirements if any to fulfil the bye-laws.

On the basis of above information, a plan showing the position of machines, flow of work and material holding devices etc. is prepared to scale on a drawing sheet. The layout is mainly planned by trial and error is laying out, modifying and relaying out.

The various tools and techniques used for layout planning are as following:

1. Operation process charts
2. Flow process charts
3. Process flow diagram
4. Machine date cards
5. Templates
6. Scale models

3.5.1 Operation Process Chart

The manufacturing process is divided into separate operations with the help of the operation process chart. It shows the points at which materials are introduced into the process and the sequence of various operations and inspections other than material handling.

The operation process chart is meant for new plant which is to be laid out. This chart represents the basic activities required for producing a product. Since it presents the overall visualisation of the process, basis for studying possibilities for the improvement of operations by elimination, combination, rearrangement or simplification is available.

3.5.2 Flow Process Chart

This chart is a graphic representation of all the production activities occurring on the shop floor. It may be considered as an elaboration of the operation process chart which includes transportation, storage and delay. The data required for preparing the flow process chart are collected by tracing the actual flow of work occurring in the unit/plant., from the receipt of raw material to the completion of the product. These data include the distance moved and the time required for the operation.

The flow process chart provides the complete information for the analysis and improvement of the unit/plant operations as a whole. On the basis of this analysis operations may be combined, rearranged or eliminated. Work station, storage space and inspection may be reallocated to minimize distances moved and labour time. An improved flow process chart provides a basis for revising an existing plant layout. The charts are also utilized to check and verify the efficiency of a proposed new layout.

3.5.3 Process Flow Diagrams

This diagram is used to supplement the flow process chart. It is the diagram of building plan representing graphically the relative position of productive machinery storage space, gangways etc. and path followed by men or materials. All routes followed by different items are shown by joining symbols with straight lines.

It is possible to trace out the undesirable characteristics of the layout which are responsible for increased transportation and delay by studying the process flow diagrams and flow process chart. It also shows nature of back tracking of present layout which there by helps in improving the layout.

3.5.4 Machine Data Cards

These cards give complete specification of each machine to be installed showing its capacity, space and other requirements, foundations methods of operation, maintenance and handling devices of machines etc.

3.5.5 Templates

After studying the flow process chart, process flow diagram and machine data cards, a floor plan is prepared by fixing the area occupied by each item (machine/equipment, benches, racks, material handling equipment etc.) to be erected in the shops. Now from the thick sheets of cardboard, plywood or plastic on the same scale pieces of sheet are cut (known as templates) to represent various items which are to be housed in the plants and are placed on the floor plans at suitable locations. These templates are arranged in such a way so as to provide the best layout.

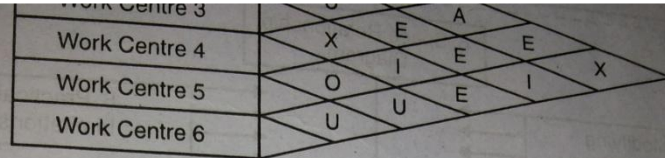
This procedure makes the layout visual before actually drawn and is carefully examined. The changes if any are in corporated before making the actual layout drawing.

3.5.6 Scale Models

It is an improvement over the template technique. In this tool, instead of templates, three dimensional scale model is utilized. These models may be of wood plastic or metals. When these are used on a layout, series of additional information about the height and of the projected components of the machines are obtained. This tool is useful for complete layout which initially requires huge investment.

QUESTIONS

1. Describe the principles of Plant Layout. Also describe plant layout by fixed position. *(K.U.K., B. Tech., 1995)*
2. Write a note on factors affecting Plant Layout. *(K.U.K., B. Tech., May, 1989, 1995)*
3. What do you understand by the term Plant Layout ? What are the principles of a good plant layout? *(K.U.K., B. Tech., May, 1995)*
4. (*a*) Describe the different types of Plant Layout.
   (*b*) Explain various principles of Plant Layout. *(K.U.K., B.Tech., 1997)*
5. A plant is presently organized on a process layout basis. It is contemplated to replace the layout as a product layout.
   (*a*) Prepare a statement for management in which you specify the circumstances that would justify such a change over.
   (*b*) Assuming that the change over is to take place, what data would you require before planning the stages of such a change? *(K.U.K., B.Sc. Engg., 1989)*
6. State the advantages and disadvantages of selecting an urban location and rural location for plant site. *(K.U.K., B.Sc. Engg., Sept., 1992)*
7. Write a note on the factors affecting plant location. *(K.U.K., B.Sc. Engg., 1989)*
8. What are the factors affecting plant location? Discuss. *(K.U.K., B.Sc. Engg., Dec., 1978)*
9. Give the comparative advantages and disadvantages of big city and a town for factory site selection.
10. Discuss how far the site of a factory would influence the cost of production of the product being manufactured?
11. Write a short note on locational economics.
12. Discuss the principles of Plant Layout in the industry.
13. What is the difference between the functional layout and product layout of machine? State the advantages and limitations of the two. Explain the two with the help of a diagram.
14. Give the main principles of Plant Layout. What advantages are derived from efficient layout in (*i*) Manufacturing cost (*ii*) production control (*iii*) Coordination and (*iv*) Initial investment ? *(Management Science, Sec-B, 1976)*
15. Define "Plant Layout" Give the important objectives of a specific plant layout.
16. Describe the relationship between the development of a plant and the determination of future demand schedules for buildings.
17. What do you understand by "Plant Design"? Discuss the various factors to be considered in deciding the location of a plant.
18. What is the distinction between a product and process layout? What are the conditions for which each type is appropriate and why ?
19. Attempt the following:
    (*a*) When would you prefer a product layout?
    (*b*) Under what conditions would you recommend process layout for a plant.
20. "Plant location is a recurring problem involving business survival". Evaluate this statement.



Solution.

2	1	3
5	4	6

2 × 3 grid

or

2	5
1	4
3	6

3 × 2 grid

2.2.10. Plant Layout Procedure

The ideal procedure for a plant layout is to build the layout around the productive process and then design the building around the layout. This may not be possible always, because the plant building may already be existing or the shape of the plant site may not permit the construction of a building to house the productive process. Ultimately one has to strike a balance between the two approaches. However, various procedural steps involved in plant layout have been listed below :

(1) Accumulate basic data.

(2) Analyse and coordinate basic data.

(3) Describe the equipment and machinery required.
(4) Select the material handling system.
(5) Sketch plan of the plot for making factory building.
(6) Determine a general flow pattern.
(7) Design the individual work station.
(8) Assemble the individual layout into the total layout.
(9) Calculate storage space required.
(10) Make flow diagrams for workstations and allocate them to areas on plot plan.
(11) Plan and locate service areas.
(12) Make master layout.
(13) Check final layout.
(14) Get official approval of the final layout.
(15) Install the approved layout.

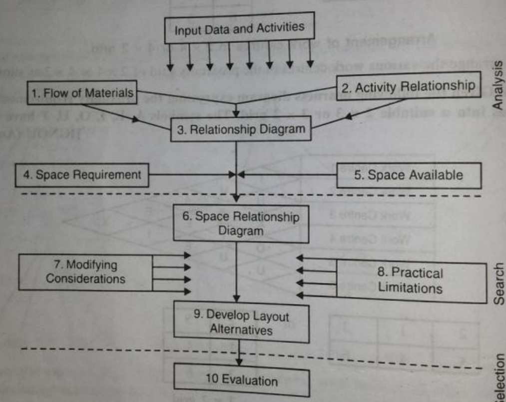


Fig. 2.22. Systematic Layout Planning Procedure.

The Systematic Layout Planning (S.L.P.) procedure suggested by Francis and White (1974) is shown above. We see that once the appropriate information is gathered, a flow analysis can be combined with an activity analysis to develop the relationship diagram. Space considerations when combined with the relationship diagram lead to the construction of space relationship diagram. Based on the space relationship diagram, modifying considerations and practical limitations, a number of alternative layouts are designed and evaluated.

p2

Computerised Layout Planning

Over the years, computer programme has been developed to guide the layout engineer in planning the best possible layout. Computerised layout planning can improve the search of the layout design process by quickly generating a large number of alternative layouts. As per the latest trend, these are the following :

(1) CORELAP (Computerised Relationship Layout Planning) : It begins by calculating which of the activities in the layout is the busiest or most related. The sums of each activity's closeness relationships with all other activities are compared and the activity with the highest total closeness relationship (TCR) count is selected and located first in the layout matrix. This activity is named **Winner.** Next, an activity which must be close to the winner is selected and placed as adjacent as possible to winner. This activity is denoted as A (closeness absolutely necessary) and is named **Victor.** A search of winner's remaining relationships for more A-related victors is then made. These are placed, again, as close to each other as possible. If no more A's can be found, the victors become potential winners and their relationships are searched for A's. If an A is found, the victor becomes the new winner, and the procedure is repeated. When no A's are found, the same procedure is repeated for E's (closeness Especially important), I's (closeness important), and O's (Ordinary closeness o.k.) until all activities have been placed in the layout. CORELAP also puts a value on the U (closeness Unimportant) and X (closeness not desirable) relationship.

(2) ALDEP (Automated Layout Design Programme) : It uses a preference table of relationship values in matrix form to calculate the scores of a series of randomly generated layouts. If for example, activities 11 and 19 are adjacent, the value of the relationship between the two would be added to that layout's score. A modified random selection technique is used to generate alternate layouts. The first activity is selected and located at random. Next, the relationship data are searched to find an activity with a high relationship to the first activity. This activity is placed adjacent to the first. If none is found, a second activity is selected at random and placed next to the first. This procedure is continued until all activities are placed. The entire procedure is repeated to generate another layout. *The analyst specifies the number of layouts wanted which must satisfy a minimum score.*

(3) CRAFT (Computerised Relative Allocation of Facilities Techniques) : It is the only one which uses flow of materials data as the sole basis for development of closeness relationships. Material flow, in terms of some unit of measurement (pounds per day, in terms of skid-loads per week), between each pair of activity areas, forms the matrix to the programme.

A second set of input data allows the user to enter cost of moving in terms of cost per unit moved per unit distance. In many cases this cost input is unavailable or inadequate, in which case it can be neutralised by entering 1.0 for all costs in the matrix.

Space requirements are the third set of input data for CRAFT. These take the form of an initial or an existing layout. For new area layouts, best guess or even completely random layouts can be used. In any case, activity identification numbers, in a quantity approximate to their space requirements, are entered in an overall area of **contiguation.** The location of any activity can be fixed in the overall area through control cards. CRAFT limits the number of activities involved in the layout to 40.

2.2.11. Work Station Design

A machine operator, the machine or machines operated by him and the floor-space allotted to him for his work constitute a *work station.* Where two or more operators co-operate and work as one unit, these operators and the machines with which they work then constitute a work station. In a product or a process layout, a work station (Fig. 2.23) is the smallest indivisible space unit and consists of the following floor-spaces :

(1) The rectangular space occupied by the machine or a group of machines constituting the work station and space allowances for travel of moving parts and for projecting machine parts, such as shafts, levers, pulleys and doors.

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(2) Space occupied by the machine's motor or power source when placed within the working area.

(3) Space occupied by the worker for operating and feeding the machine and for his essential movements.

(4) Clearance for feeding the work into and out of the machine.

(5) Space for racks, conveyor stations and containers for holding materials before and after processing.

(6) Space for tool racks, work benches and auxiliary equipment which may be required for machine operation.

(7) Aisle space, conveyor space required for operation of the machine.

(8) Space for keeping the machine completely accessible for normal maintenance and repair.

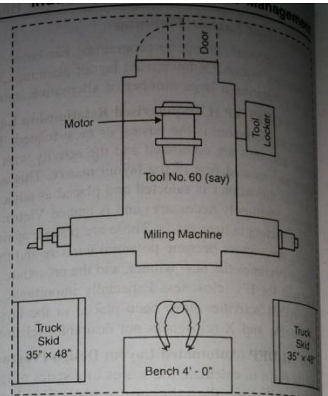

Fig. 2.23. A typical work station.

It will be seen that a work station constitutes more space than what is acually occupied by the machine proper and its operator. The objects of a work station layout should be economy of floor-space consistent with efficient working of the machine with least travelling time for the operator. By means of an efficient work station layout the planning engineer may bring about important operating economy which is one of his major activities.

Some of the savings in space may originate from utilization of common spaces for more than one purpose. Thus the space occupied by the operator in working the machine may also serve as clearance for the bench drawer. For best utilization of space, the tool locker is placed in a place which is likely to remain unused.

Selecting Specific Materials Handling Equipment

General materials handling equipment should be decided upon before the work stations are planned. The work stations are planned on the basis of this general selection of handling equipment and the flow pattern.

As the planning stage of work stations, however, specific decisions should be made as to what material handling equipment shall be actually adopted. A work station provides a space for materials handling equipment so that it may efficiently work on minimum floor space. Selecting specific materials handling equipment is therefore, important in finalizing a work station layout.

Planning and Locating Service Areas

An efficient plant should provide for locations of both manufacturing and service departments. A plant layout, which is concerned solely with the production departments, and fails to layout efficiently the service departments, is soon faced with operating problems leading to high cost of production. This layouts of production and service departments should be considered simultaneously as an integrated plan. Layouts of some of the important service departments are considered below :

1. Storage Space. Storage space should be provided for raw materials, work in process and finished goods.

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2. Tool Cribs and Toolrooms. The control tool room keeps tools, jigs, fixtures and dies and through the tool cribs these may be issued to the workers, inspection deptts and the maintenance crew.

3. Power House. Where power is generated in own plant, the power house should be located where delivery of coal and oil may be conveniently made and ashes may be easily removed and disposed off.

4. Factory Office. For effective control and coordination of the production deptt. it should be placed in closed proximity to the production deptt.

5. Locker rooms, washrooms and toilets etc. These should be situated as close to the respective deptts. as possible.

6. Personel Deptt. It should be placed not close to manufacturing area because the deptt. has to maintain the personal records of the employees and the staff.

7. General Office. The general office is usually located in separate building where the executivies may communicate with one another in a more congenial environment.

8. Other Departments. Other miscellaneous deptts. are governed by teh function they perform and their inherent requirements.

2.2.12. Line Balancing

"Line Balancing" in a layout means arrangement of machine capacity to secure relatively uniform flow at capacity operation.

It can also be said as a "layour which has equal operation times at the successive operation in the process as a whole".

Product layout requires line balancing and if any production line remains unbalanced, machinery utilization may be poor. The machine in the line will operate only say half of the time.

Let us assume that there is a production line with work stations, x, y and z. Also assume that each machine at x, y and z can produce 200 items, 100 items and 50 items per hour respectively. If each machine was to produce only 50 items per hour then each hour the machines at x and y would be idle for 45 and 30 minutes respectively while machine z will be fully loaded. Such a layout will be unbalanced one and the production lines need balancing.

As another example, a bakery would not be in balance, if the oven continuously baked loaves at the rate of 600 per hour and wrapping machine could only wrap 400 loaves per hour. Hence the production line requires balancing.

Methods of Line Balancing

(*i*) The one possibility in the right direction, at ieast as far as balancing the line is concerned, would be to increase the output.

(*ii*) The second possibility is that another product may be made close to the first one so that some idle machines may be used jointly.

(*iii*) The third possibility may be to estimate the output of the last work station. This can be taken as the minimum output of all the intermediate work stations.

Objectives of Line Balancing

A balanced layout eliminates bottle-neck operations as well as prevents the unnecessary duplication of equipment capacity. Line balancing is a major consideration in layout because a lack of balance can most easily hinder the production. For balancing it is not essential that output of each operation should be the same but the essential is to see that output of fastest machines should be multiple of the output of the remaining other machines. The following examples aim to illustrate line balancing.

Fig. 2.5. A combination layout for making different types and sizes of gears.

A combination layout is also useful when a number of items are produced in same sequence but none of the items are to be produced in bulk and thus no item justifies for an individual and independent production line. For example, files, hacksaws, circular metal saws, wood saws, etc. can be manufactured on a combination type of layout.]. End.

2.2.8. Introduction to Layout Based on GT (Group Technology) JIT (Just in Time) and Cellular Manufacturing System

Let us understand the concept of GT and JIT first before we discuss the layouts based on these practices.

Group Technology (GT). It is the replacement of traditional job-shop practice. Here the operations of the job and their sequences are analysed to form certain families of jobs. Depending on the family, a number of machines are grouped together in each work centre. These work centres are then arranged in a proper sequential order so that these families of jobs flow through the work centres smoothly. The objective here is to minimise the setting time and throughput time

Group Technology is the realisation that many problems are similar and that by grouping similar problems, a single solution can be found to a set of problems, thus saving time and effort.

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This is an improved version of Cellular Layout or Combination Layout (see Cellular layout). In the cellular layout, we observe that at each work centre concerned with one single operation/process say turning, or drilling etc., some operations are repeated. When more number of products are involved because of variation in sequencing, some products have to backtrack. GT tries to overcome the above limitations of the simple combinations given above. Instead of designing each work centre for a pure, single specialised work, in group technology, each work is a combination of specialised operations or processes. For example, if large number of products have only three operations say drilling, grinding and drilling, (repeated), there is no harm in designing an exclusive work centre catering to these three operations. Thus each work centre in group technology now becomes a combination of processes instead of being limited to one single process. That particular combination is determined by analysing types of products, their operations and sequencing.

Just-in-Time (JIT). (See Section 9.30 also) Think of a situation where we produce the required goods only at the time when they are needed and in the quantity that is needed, and where this holds good for finished products and semi-finished products both. If such a situation materialises, the inventories of the finished goods and work-in progress would be almost nil. Now if we make our raw materials suppliers agree that they should deliver their goods only at the time and in the quantities we need them to, then we are almost eliminating raw materials inventories as well. We shall then have virtually zero inventories (or near about zero). This is the concept of JIT production system founded by Taiichi Ohno (a Vice President at Toyota) and is first successfully implemented at the Toyota Motor Company's plant in Japan and now being tried at various manufacturing industries all over the world.

JIT is an approach to material management and control designed to produce or deliver parts and materials just when required in production.

Whatever materials and components are needed for a shift are received at the beginning of the shift and converted into finished goods leaving nothing to be carried forward at the end of the shift. It means that the various vendors are working in consonance with the manufacturing organisation as a single team, dedicated to act in unison, wherein production schedule and supply schedules are matched perfectly and operate in an absolute synchronized manner.

Layouts (Based on GT and JIT). To illustrate GT let us consider a family that produces two families of parts. The first group of parts are cylindrical (Fig. 2.10) and require operations on a lathe, milling machine and drilling machine. The second family requires shearing, milling and drilling. The traditional process layout shown in Fig. 2.11 groups shears, lathes, milling machine and drilling machine in separate departments. As parts from each family pass through milling and drilling departments in batches, new setups (it creates queues of work/load) on the machines must be performed. The GT concept establishes a separate machine grouping of milling and drilling machines for each part family (Fig. 2.12) Since part families have similar features, retooling is much easier and hence setup times are reduced and the system operates in the fashion of a production line.

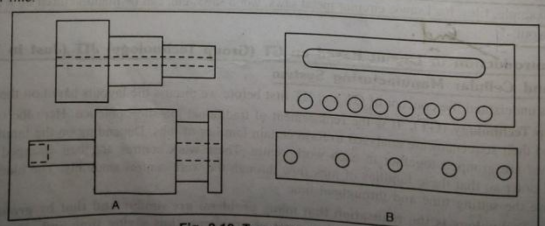

Fig. 2.10. Two-part Families.

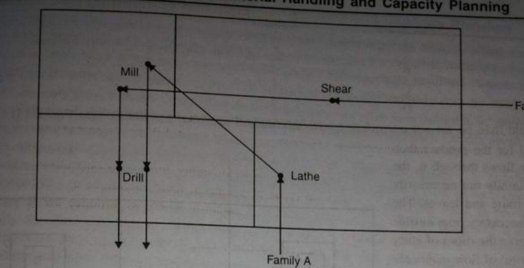

Fig. 2.11. Process Arrangement.

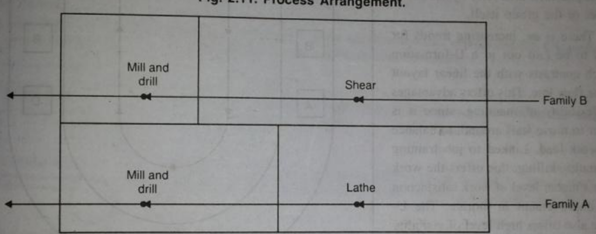

Fig. 2.12. Group Tech. Layout.

Organization into "family" or "group" will not only offer the ability to reduce time, it also simplifies material flow, speed of the material flow through the system and production content made easier since scheduling of machines becomes less complex, fewer tools and materials may be required and material handling costs can be reduced. Savings in setup time and increased production potential may be of significant economic benefits to the firm.

Let us take another example of a product having six operations and a technical route as shown below in illustrating a U-shaped cell layout of GT.

Operation	*Processor*
1	A (say turning)
2	*B* (say drilling)
3	*A*
4	*C* (say milling)
5	*C* (say grinding)
6	*B*

If this is a member of a family, the other members will have similar technical routes. Demand for the ***whole family*** may justify the group comprising the following processors :

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Processor	Number
A	2
B	2
C	1
D	2

The cell could than be set out *according to the mechanical needs of the family* (see Fig. 2.13)

The material for the product then enters the cell or flows through it, the members of the family not necessarily taking the same route and leaves. The only monitoring necessary *from outside the cell* is to observe the times of entry and exit. The control of flow *within the cell* is provided internally by the group leader or the group itself.

There is an, increasing trends for cells to be laid out in a U-formation which contrasts with the linear layout of the flow line. This offers advantages of flexibility of manning, since it is easier to move staff around, to balance the work-load. Linked to job training and multi-skilling, this offers the work force a higher level of work satisfaction and improvement in morale. The U-shape also offers high level of visibility to cell members to see work flows and identify and cope with problems by anticipation. The U-shaped cells of GT is also advocated in the implementation of the Just-in-time (JIT) philosophy—the instantaneous satisfaction of customer's demand with zero waste.

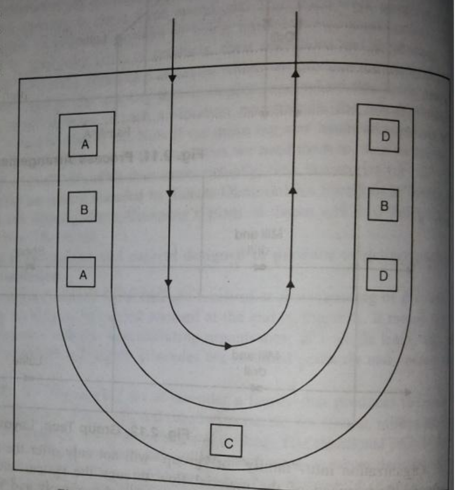

Fig. 2.13. U-shaped Cell Showing One-item Flow.

Lean Manufacturing (Agile Manufacturing). It is a systematic approach to identify wastes of all non-value added activities through continuous improvement making use of JIT production technique. The traditional manufacturing way of thinking has been "cost + profit = selling price" but the lean way of thinking is "selling price – cost = profit." Under this redefined scenario, the only way to survive in the market is to decrease cost by eliminating all forms of waste. Lean manufacturing achieves reduction in cycle time, on time delivery, improvement in quality and decrease in scrap/rework.

2.2.9. Methods of Plant Layout

A layout furnishes details of the building to accommodate various facilities like workers, materials, machinery etc. In addition it integrates various aspects of a design of a production system. The information required for plant layout includes dimensions of workplaces, sequence of operations, flow pattern of materials,

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storage space for raw material, in-process inventory and finished goods, offices, aisles, toilets, canteen etc. There is no single universal technique leading to the best layout; the different techniques independently or in conjunction with other techniques may be employed at different stages involved in plant layout.

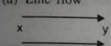
During different development stages of a layout the following methods may be used.

(1) Process Flow Charts. They show, how different component parts assemble in sequence of operations to form sub-assemblies which in turn lead to assemblies (finished products). Details about flow charts have been discussed in chapter (3) of Work Study.

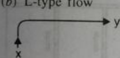
(2) Material Movement Pattern. The principle of minimum movements (*i.e.* number of movements and distance travelled in one move) forms the basis for optimum effective flow of each operation or process or material. The principle of minimum movements reduces material handling costs, in-process inventory and space for processing and supervision and control becomes simpler. While designing a new plant layout, generally the flow patterns are decided earlier and then a system of facilities (machinery, material and building) is designed and built around the flow pattern. Various flow patterns that are employed in designing the layouts with their characteristics are shown below (Fig. 2.14)

Flow Pattern — *Characteristics and Place of Use*

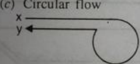
(*a*) Line flow — Simplest, material enters at one end (*X*) and leaves at other end (*Y*). It is preferred in buildings having long lengths and smaller widths.



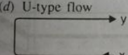
(*b*) L-type flow — Resembles line flow and is used where buildings are more wide but less long as compared to line type buildings.



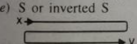
(*c*) Circular flow — Preferred for rotary handling systems. Different work stations are located along the circular path. Raw material enters at *X* and finished goods come out from *Y*.



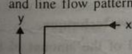
(*d*) U-type flow — Supervision is simpler as compared to (*a*) and (*b*) above. Raw material entrance and finished goods exit are on the same side. (*c*) and (*d*) are preferred in square-shaped buildings.



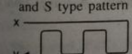
(*e*) S or inverted S — Preferred for production lines longer than (*d*) and in square shaped buildings. The system is compact, space has been better utilized and supervision is efficient.



(*f*) Combination of U and line flow pattern



(*g*) Combination of line flow and S type pattern



(*h*) Combination of flow and circular type — As compared to line flow, these systems need smaller building line lengths.

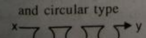


Fig. 2.14. Various flow patterns.

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(3) Layout Analogues. They cover two dimensional cutouts or templates and three dimensional models made to scale to show actual floor space utilization.

(*a*) ***Two-Dimensional Cutouts or Templates.*** They are made to scale usually on a scale of 1:50 of cardboard, coloured paper or plywood showing the plan of the various facilities and the building. They show the actual floor space utilization. Templates save a lot of time and labour which otherwise would be spent in making drawings for each alternative plant layout arrangement. Figure 2.15 shows a two-dimensional block template giving details of a machine outline.

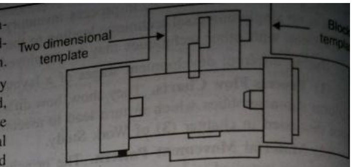

Fig. 2.15. Two-dimensional and block template

(*b*) ***Three-Dimensional Models.*** They are scale models of a facility and more near to the real situati as, besides length and width they show the height of a facility also. Models made up of wood or die-ca plastic, can be made for production machines, workers, material handling equipment or any other facili Models are much more effective, impressive and presentable as compared to drawings or two-dimension templates especially when multistoreyed plant layout is to be designed. Figure 2.16 shows a three-dimension model of a roller conveyor, a marking table, a cupboard and an inspection table.

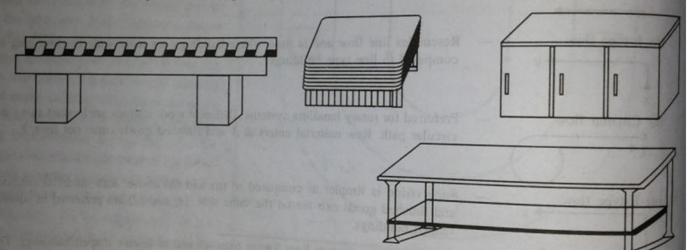

Fig. 2.16. Three-dimensional models.

4. Correlation Chart. It involves drawing a grid with rows representing alternative solution as to whic item will be made in which floor of a multistoreyed building. The various constraints are taken care of a regards to the availability or non-availability of cranes, machines, special attachments etc. floor wise and the the correlation chart is prepared for the visual representation for the **what-where technique.**

5. Travel Chart. A travel chart as the name suggests is a chart of record of the amount of travel b material in-process while going from machine to machine or from one department to another. The amount o travel depends upon the frequency of movements between sections or departments. A travel chart help improving the existing plant layout.

The following example will explain a travel chart.

Existing plant layout showing the locations of various departments (*A* to *F*) is given in Fig. 2.17.

A	*B*	*C*
D	*E*	*F*

Fig. 2.17. First Step : (Existing layout).

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2nd step : Movements from A to B are 20; B to A, 10; B to C, 15; A to F, 25; C to D, 30; D to C, 50; D to F 40; E to F, 10 and F to E, 15.

3rd step : A square grid is drawn and the various movements are marked.

4th step : Figure 2.18 is simplified by combining movements like A to B (20) and B to A (10) which involve same distance and, therefore, total movement $B \rightleftarrows A = 20 + 10 = 30$.

To \ From	A	B	C	D	E	F
A		10				
B	20					
C		15		50		
D			30			
E						15
F	25			40	10	

Fig. 2.18.

To \ From	A	B	C	D	E	F
A						
B	30					
C		15				
D			80			
E						
F	25			40	25	

Fig. 2.19.

This simplified travel chart (see Fig. 2.19) shows the movements as follows :

$$A \rightleftarrows B = 30$$
$$B \rightleftarrows C = 15$$
$$C \rightleftarrows D = 80$$
$$A \rightleftarrows F = 25$$
$$D \rightleftarrows F = 40$$
$$E \rightleftarrows F = 25$$

According to these figures maximum number of movements are between departments C and D, hence in the plant layout these two departments should be side by side. The next lesser number of movements are between D and F, hence D and F should also lie closer to each other and so on. As a result the existing plant layout can be modified as shown in Fig. 2.20.

C	D	A
E	F	B

Fig. 2.20. Modified Layout.

Departments C and D (80), D and F (40), A and B (30), A and F (25), E and F (25) are closer to each other whereas B and C which have minimum number of movements (*i.e.* 15) between them, are away from each other.

A travel chart is advantageous because it brings out the relative importance of having different pairs of departments close to each other but it gives an optimum linear arrangement which may not be always required.

(6) Load Path Matrix Method. The method aims at reducing the transportation of in-process inventory from section to section. Like travel chart it also helps deciding the position of one department in relation to the other. The ultimate purpose is to modify the existing layout or the preliminary layout made by other techniques. The departments having mass flow of material or goods are placed close to each other.

PLMH BOOK 3

- BY R.K SINGAL

PLANT LOCATION AND LAYOUT

Introduction; Factors affecting the site selection of plant; Plant layout; Factors affecting plant layout, Types of plant layout. Workstation design, Techniques of making layout.

2.1 INTRODUCTION

Location of a manufacturing plant is critical to its smooth running. The selection of site and equipment are important aspects of project to derive maximum operative economy and effectiveness. An ideal site certainly contributes to the smooth and efficient functioning of an enterprize. It not only saves on costs but also enhances productivity and profits. An ideal location is a boon to a manufacturing unit to grow, diversify and prosper, as well as provide quality products on an ongoing basis.

Plant layout may be defined as physical arrangement of industrial facilities. The arrangement includes the spaces needed for material movement, storage, indirect labourers and all other supporting activities or services as well as operating equipment and personnel. Plant layout is:

(*i*) Placing the right equipment.
(*ii*) Coupled with the right method.
(*iii*) In the right place.
(*iv*) To permit the processing of a product unit in the most effective manner.
(*v*) Through the shortest possible distance.
(*vi*) And in the shortest possible time.

2.2 FACTORS AFFECTING THE SITE SELECTION OF PLANT

The location of an enterprize has to be carefully selected. A wrong choice sometimes proves fatal for the enterprize. The selection of a suitable locality depends on a number of factors. Further, each factor is influenced by a number of other factors. So a thorough analysis of the location to be selected is to be undertaken before a particular site is finalized. Following list has been prepared by the United States Department of Commerce to help the site selection.

I. **Location of Production (Raw) Materials**

A. What production materials exist in the area?

B. In what volume are the production materials available?

C. What is the quality of each production material?

D. How accessible are the available material?

Does the nature of such production materials (quantity, bulk, perishability, etc.) or any unusual advantage attendant thereto definitely favour plant location at or near site or source?

II. **Labour**

A. What is labour force of the area?

B. What is the quality of the available labour force?

C. What is the character of the labour force?

D. What quantity of labour is seasonally available?

1. Is a large supply necessary?
2. Are special skills required?

III. **Sites**

A. How much land is available for industrial expansion?

B. What are the soil and topographic features?

C. At what cost and terms can land be purchased or leased?

D. What facilities are now or will be available?

E. What industrial floor space is or will be available in existing structures?

1. Is a large area needed?
2. Must the site have special features, such as topographic soil conditions, transportation facilities, low costs, etc.?

IV. **Industrial Fuel**

A. What industrial fuel is available for additional industry?

B. How dependable is the supply?

C. At what cost is the fuel available?

1. Is low cost heat a major factor in processing?
2. Is a particular fuel required?

V. **Transportation Facilities**

A. What transportation facilities are available?

B. What is the rate situation?

P-r2

1. Do materials and/or products require prompt and/or low cost movement ?
2. Does product or raw material require a special type of transportation?

VI. **Markets**

A. What is the trading area generally served by this location?

B. What is the general quality of the market?

1. Are time and distance vital matters to reach the market?
2. Is price of quality a vital market factor?

VII. Distribution Facilities

A. What agencies and services are available?

1. Are there channels for marketing complex and do they require special financing, inspection, warehousing, storage or terminal facilities?

VIII. Power

A. What kind of industrial power is available?

B. How dependable is the power available?

C. At what cost is the power available?

1. Is power a significant factor?
2. Is sufficient surplus power available?

IX. Water

A. How much water is available for additional industry?

B. What is the quality of the water supply?

1. Is significant quality of low cost water required in processing?
2. Whether the required quantity is available?

X. Living Conditions

A. Are adequate facilities available for education, recreation, shopping, religious and social life, health and professional services?

B. Is sufficient housing available?

1. Will the industry employ enough people to make housing and environment significant factors?

XI. Laws and Regulations

A. What law and regulation exist of significance to prospective industry?

1. Is the industry subject to special local and/or state regulations?

XII. Tax Structure

A. How favourable is the tax structure to industry?

1. Is the capital investment of such a size that the tax rate or assessment policy will be important?

XIII. Climate

A. What are the climate characteristics of the area?

Optimum site is selected on the basis of a comparative survey of the alternative sites in question.

2.3 STEPS IN ENTERPRIZE LOCATION

The following steps should be followed for choosing a plant location:

(*i*) Selection of the region.

(*ii*) Selection of locality.

(*iii*) Selection of the exact site.

Different surveys as per # 2.2 should be conducted and significant factors should be analysed. The important factors in the selection of region, locality and site are tabulated in Table 2.1.

P-R3

1. Availability of Raw Materials

The region provide at least greater part of raw material required to ensure a continuity of supply at reasonable price.

Table 2.1 Important Factors in the Selection of a Site

Sl. No.	Factors	Selection of region	Selection of locality	Selection of site
1.	Availability of raw materials	√		
2.	Nearness to markets	√		
3.	Availability of power	√		
4.	Transport facilities	√		
5.	Suitability of climate	√		
6.	Government policy	√		
7.	Competition between states	√		
8.	Availability of labour		√	
9.	Civic amenities for workers		√	
10.	Finance and research facilities		√	
11.	Availability of water and fire-fighting facilities		√	
12.	Local taxes and restrictions		√	
13.	Momentum of an early start		√	
14.	Personal factors		√	
15.	Soil, size and topography			√
16.	Disposal of waste			√
17.	Housing facilities for workers			√
18.	Unecumbered land			√
19.	Good scenery			√
20.	Road, rail and water connections			√

2. Availability of Skilled and Unskilled Labour

Proper labour required should be available in the area. It is costly to bring labour from other areas.

3. Nearness to the Source of Motive Power

The area should provide cheap and reliable power, soft water and adequate sewage disposal facilities.

4. Nearness to Market

Nearness to market has to be taken into account.

P-R4

5. Availability of Transport Facilities

Transport should be available at a reasonable cost.

6. Nuisance Problems

An arrangement has to be made, if not available, for smoke, noise, odour or smog existing in the area.

7. Suitability of Climate

Climate does influence the product and its quality.

8. Topography

Flat, cheap, marshy land, sea, lake, river location, vegetation in the area, elevation above sea level.

9. Soil Condition

This determines the nature of foundation, drainage requirements.

10. Water Supply

Quality of water is important. Softening and treatment plant, if required, will have additional cost.

11. Waste Disposal

Local regulations may require additional facilities for treatment of effluents prior to discharge to main stream.

12. Nearness to Rail Connection or Highway

13. Local Legislation and Municipal Laws

Laws for sanitation, air and steam pollution.

14. Tax concessions and other incentives.

15. Community attitude

Towards manufacturing activities and outside investors.

16. Living conditions for labour and management.

Climate, recreational facilities, quality of schools, religious institutions, medical facilities, hospitals and other factors.

"Most advantageous location is that at which the cost of gathering material and fabricating it plus the cost of distributing the finished product to the customer will be minimum". Kimbal and Kimbal.

2.4. PLANT LAYOUT

Plant layout is the most effective arrangement of machines, men, materials handling, service facilities and passage required to facilitate efficient operation of production system. It depends upon production system and type of product.

2.4.1 Objectives of Plant Layout

The primary goal of plant layout is to maximize profits. This can be achieved by:

1. Minimum material handling.
2. Reduced manufacturing cost.
3. Ensure output in quantity and quality.
4. Flexibility to meet changing needs.
5. High turnover of work-in-process.
6. Low investment in equipment.
7. Effective use of floor space.
8. Best utilization of equipment and facilities.

P-R5

9. Reduced work delays and stoppages.
10. Effective utilization of manpower
11. No back-tracking.

2.5 FACTORS AFFECTING PLANT LAYOUT

The plant layout should be designed on the following principles:

1. Single Operating Unit

All the manufacturing and service units should be properly integrated into single operating unit.

2. Minimum Movements

All movements of men, materials, work-in-process should be minimized while designing a single operating unit.

3. Smooth Flow

The product under manufacture should move smoothly towards its completion without interruption, congestion or back-tracking.

4. Space Utilization

All space should be utilized effectively in horizontal and vertical direction.

5. Safety of Workers

The layout should ensure safety of workers and satisfaction to them.

6. **Flexibility**

The layout should ensure sufficient flexibility to take care of rearrangements of production facilities when required.

The *plant layout* is affected by the following factors:

1. Plant Location

The shape, size and topology of the site affect the plant layout. Plant site also influences the type of buildings, internal transport and material movement and scope of future expansion. All these factors affect the plant layout. Therefore, plant layout is a compromise between ideal layout and the limitations imposed by plant site.

2. Plant Environment

The plant climate consisting of heat, light, noise, ventilation etc., should be taken care during plant layout.

3. Product

Type of product influences the plant layout. Standardised product needs product layout customer-made product needs process layout, heavy and bulky product may require fixed position layout.

4. Production System

The type of production system has maximum effect on plant layout. Mass production system requires product layout batch production system requires process layout.

P-R6

5. **Space Requirements**

Space requirements are dictated by Factory Act, 1948. Sufficient space should be provided around the equipment to ensure safety of the worker.

6. **Repair and Maintenance**

Space must be provided to carry out repairs and maintenance of plant and machinery.

7. **Balancing of Machine capacity**

Proper balancing of machine capacities helps to avoid bottlenecks in the movement of materials.

8. **Management Policy**

The maximum product size to be handled will determine the size of the workstation. Layout is also affected if sufficient flexibility is to be ensured. The plant layout should match with management policy.

2.6 TYPES OF PLANT LAYOUT

The machines and facilities within department may be arranged along work flow or as per function of the machine. There are four basic types of layouts.

1. Process layout.
2. Product layout.
3. Combination of process and product layout.
4. Fixed position layout.

2.6.1 Process Layout

It is also called functional layout. Machines and operations of same type are grouped together without regard to any particular product. Same operations are performed in one area. For example, drilling machines, milling equipment, welding machines, etc., are grouped together in separate areas. The process layout is used when:

1. Production volume is low.
2. Variety of products is high.
3. The demand for the product is small or intermittent.
4. General purpose low-cost machines are required.
5. Machines and processes producing unwanted noise vibration, fumes or heat can be isolated.

Examples: Tailor-made jobs, department stores, hospitals etc.

P-R7

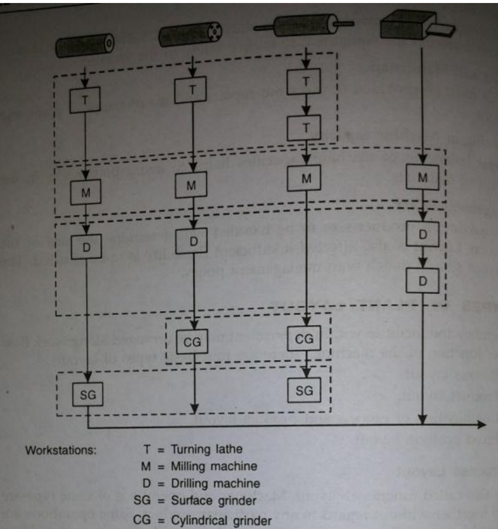

Fig. 2.1. (a) Process layout.

Advantages

1. Better machine utilization, low machine investment cost.
2. A variety of products and frequent changes in sequences of operations are feasible.
3. Suitable for intermittent demands.
4. Less sensitive to:
   (*a*) Machine breakdown.
   (*b*) Material availability.
   (*c*) Workers absence.
5. Maintenance easy.
6. Job pay system possible.

Disadvantages

1. Operations cost high due to low productivity of general purpose machines.
2. Work routing, scheduling and accounting are costly due to changes with every new order.
3. Materials handling and transportation costs high.
4. Inventories of work-in-process high.
5. Large storage space required because of slow movement of materials.

P-R8

6. Difficult balancing between labour and machines.
7. Production control is difficult.
8. Needs more inspections and better coordination.

2.6.2 Product Layout

The workstations are arranged according to sequence of operations by which the product is made. Product layout is used in continuous product system under the following conditions:

1. The number of final products are less.
2. The components are highly standardized and interchangeable.
3. The volume of production is high.
4. The demand of the product is steady.
5. The continuity of raw material can be maintained.

Examples: Automobile assembly, food processing, furniture manufacture, etc.

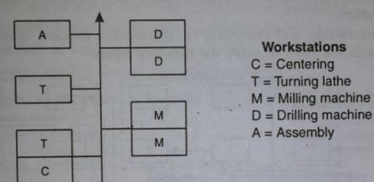

Fig. 2.1. (b) Product layout.

Advantages

1. Reduced material handling.
2. Low work-in-process, production time, and inventory cost.
3. Effective use of labour through:
   (a) Job specialization.
   (b) Low training cost.
   (c) Ample labour supply.
   (d) Less skilled workers.
4. Controls simplified.
5. Inspection, work-in-process, floor areas and aisles are reduced.
6. Simple production planning and control, better coordination.
7. Smooth and continuous work flow.

Disadvantages

1. High initial equipment cost.
2. Chances of work stoppages.
3. Inflexibility to changes in design and layout.
4. Low labour productivity due to highly repetitive nature of work.
5. Inspection becomes difficult.
6. Pace of working depends upon the pace of the slowest machine.

P-R9

7. More machines are needed as:
   (a) Machines are arranged operationwise.
   (b) Standby machines are needed to avoid complete shutdown.

2.6.3 Combination Layout or Group Layout (Group Technology)

This layout combines the advantages of both the product and process layout. In actual industries, pure layouts are not possible. The plant is divided into shops. The manufacturing shop is partitioned in a few groups of machines. Each group produces similar set of components. Group technology (*GT*) uses similarity of processing of components. Group technology facilitates optimization of production scheduling.

The group technology avoids wastage in the following ways:

1. By clubbing similar activities, time in changing from one activity to the next is saved.
2. Standardizing of activities help to focus only on differences and avoids duplication.
3. Efficient storing and retrieving of information reduces search time and eliminates the need to solve the problem again.

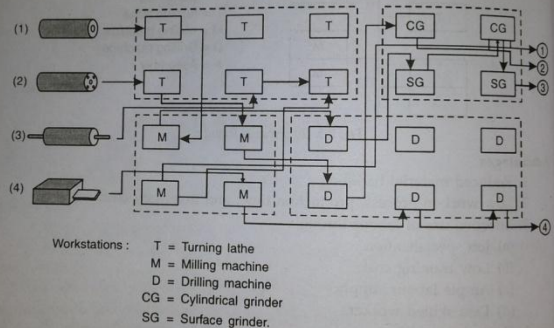

Fig. 2.1. (c) Group layout.

Figure 2.1(*a*) shows a manufacturing shop partitioned into *GT* shop. The four components (Turning lathes, Milling machine, Drilling machine and Grinders form the component family.

Advantages

1. Machines set-up time and machining times are reduced.
2. Reduction in material handling cost.
3. Work-in-process inventory reduced.
4. Production time is reduced.
5. Simplification of production planning functions.

P-R10

Disadvantages

1. Conversion to *GT* layout can be time consuming and costly.
2. Inclusion of new components into the existing component group requires thorough analysis.
3. Change of input component-mix may change cell structure.
4. Change in batch sizes may require change in number of some machines.
5. Some components are processed by more than one machine groups. Such components lead to complexity in machine loading.

2.6.4 Fixed Position Layout

The product being bulky remains at one location. The equipment and the workers move to the product. The layout is used under the following conditions.

1. The manufacturing operations require simple tools and machines.
2. Only one or a few big items are to be manufactured.
3. The cost of moving the components/product is high.
4. The skill of workmanship is high.
5. Product quality lies on group of workers.

Example: Manufacture of aircrafts, locomotive, ship, shipyard etc.

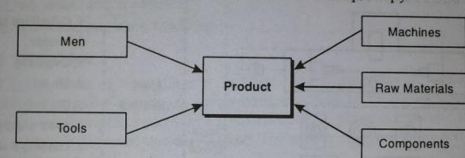

Fig. 2.1 (d) Fixed Position Layout.

Advantages

1. Handling of components/product is minimized.
2. Highly skilled operators complete their work at one point.
3. Frequent changes in product design and in sequence of operations are possible.
4. The layout is suitable for a variety of product and for intermittent demand.
5. It is very flexible.

Disadvantages

1. Highly skilled workers are required.
2. Machines/tools require more time to reach the location.
3. Low labour and equipment utilization.

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2.7 WORKSTATION DESIGN

Workstation design affects the production efficiency and accuracy of the operation being performed. In the design of the workstation, the following space required should be provided.

1. Worker to operate.
2. Machine including projection.
3. Motor over-hung.
4. Bins for storing incoming and outgoing materials.
5. Tools and other supplies.
6. Jigs, fixtures and other accessories.
7. Loading and unloading of large workload.
8. Material handling equipment.

In addition to above space provisions, the following factors are considered in the design of workstation.

1. Easy access to safety stops in case of emergency.
2. Easy access to the machines for lubrication, cleaning, maintenance and repair work.
3. Convenience of foundation and machine installation.
4. Aisle space between machines.
5. Appropriate lighting, ventilation and safety arrangements.
6. Requirements of Factory Act, 1948.

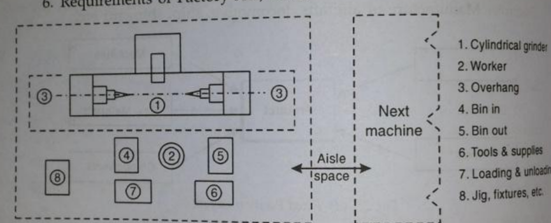

Fig. 2.2. Workstation layout.

2.8 TECHNIQUES OF MAKING LAYOUT

The plant layout furnishes the details of the building to accommodate machines, materials, men, etc. For efficient layout, the following basic information is needed for further planning:

1. Dimensional plan of space to be used for layout.
2. Product specification and bill of materials.
3. Value and rate of production.
4. Description of operation, their sequence and standard times in production process.
5. The equipment and machining required to perform operation.
6. Workforce by size and skill type.
7. Material holding system to be used.
8. Amount of material, buffer stock required at each workstation.

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9. Size of finished and semi-finished inventory.
10. Type of communication and fire fighting equipment required.
11. Special requirement as per Factory Act, 1948.

On the basis of above information, a plan showing the position of machines, flow of work and material handling devices is prepared on a scaled drawing. The layout is mainly by trial and error and requires repeated modifications and relaying.

The various techniques used for making a plant layout are as followings:

1. Flow diagram.
2. Templates.
3. Distance volume matrix.
4. Travel chart.

2.8.1 Flow Diagram

Flow diagram is the building plan graphically representing the relative position of production machine, storage space, aisles, etc. It also includes the path followed by men and materials. All routes followed by different components are shown by joining symbols with straight lines.

This diagram can be used:

1. To trace out defects in the layout which can cause increased transportation of work and materials.
2. To trace out back tracking.

2.8.2 Templates

On the basis of flow diagram, a floor plan is prepared by fixing space for different items like machines, equipment, material handling equipment, racks, benches, etc. Templates are made from cardboard, plywood, plastic sheet on the same scale for different items as above: These templates are arranged to provide the best layout.

2.8.3 Distance Volume Matrix

This method is used to reduce transportation of in-process inventory from one department or section to other. The relative position of different departments are decided. The departments having mass flow of material or goods are placed close to each other. Accordingly, the plant layout already prepared is modified.

2.8.4 Travel Chart

A travel chart is a chart of the amount of travel by material in-process while going from one machine to another or from one department to another. The amount of travel also depends upon the frequency of movement between sections or departments. A travel chart helps to improve the existing plant layout.

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SUMMARY

UNIT-II
MATERIAL-HANDLING

- *DEFNITION:*
- *According to H.A. Harding*
- *"improvement in handling can mean faster production , higher plant capacity , lower stock in process and less damage to product in stages. It can force other improvements in production methods and materials.'' it may be noted that the best handling is ''NO HANDLING " and if this cannot be ac ," MINIMUM HANDLING" should be tried,*

16 Chapter

Material Handling

"Material handling is a specialized activity for modern manufacturing systems and it covers all types of handling viz., raw materials, semi-finished materials and finished products through production as well as storage space. One of the significant characteristics of material handling is that it does not add any value to a product but it adds a significant element of cost which lies within the range of 20 to 50 percent of the total cost of production.

INSIDE THIS CHAPTER

16.1 Introduction
16.2 Functions of Material Handling
16.3 Objectives of Material Handling
16.4 Engineering and Economic Considerations
16.5 Principle of Material Handling
16.6 Selection of Material Handling Equipments
16.7 Solution of Material Handling Problem
16.8 Classification of Material Handling Equipment
16.9 Relation Between Plant Layout and Material Handling

16.1 INTRODUCTION

Material handling may be considered a specialized activity for modern manufacturing units. From the time, the input material or raw materials enter the industrial unit and go out of the unit in the form of finished products, these are handled at all stages in between, no matter, on the shop floor or in the stores. It has been estimated that the average material handling cost is roughly 30 to 60% of the cost of production. This is so since majority of production time is consumed in handling materials before, during and after the manufacture. However, this cost can be reduced by proper selection, operation, maintenance and layout of material handling devices but cannot be totally eliminated.

"Material handling" refers to the movement of materials from the store room to the machine and from one machine to the next machine or work station during the process of manufacture.

The material handling problem must be analysed thoroughly at the time planning of various machines and tools needed before erection of factory building. While designing new plants, materials handling is a prime consideration and several existing plants can be modified by the utilization of modern material handling devices. The cost of production is decreased by the use of these devices since these devices increase output, improve the quality and speed up the deliveries.

16.2 FUNCTIONS OF MATERIAL HANDLING

Following are the important functions of material handling.

(*i*) To select machines/equipment and plant layout to eliminate or minimize material handling requirements, i.e. to select most efficient, safe and appropriate material handling equipment, which can fulfill material handling requirement at minimum cost.

(*ii*) To minimize the material handling cost by way of:

(*a*) Minimization of movement of semi finished items during the production process.

(*b*) Planning movement of optimum necessary pieces in one unit.

(*c*) Minimization of distance moved.

(*d*) Increasing speed of material handling operation through mechanization.

(*e*) By elimination/minimization of back tracking and duplicate handling.

(*f*) By utilization of gravity for material handling.

(*g*) To employ mechanical aids instead of manual labour to accelerate material movements.

16.3 OBJECTIVES OF MATERIAL HANDLING

The common hand shovel and the baskets were the only material handling tools, until some years ago, but now due to increasing demand for sophisticated handling equipment, material handling system has been revolutionized all over the world.

The main objective of the efficient materials handling is to decrease the costs. Materials handling equipment does not come under the production machinery but is an auxiliary equipment which can improve the flow of materials which in turn shall reduce the stoppages in production machines and thus increases their production. In brief followings are the objectives of material handling.

(1) Costs Reduction by:

(*i*) Decreasing inventory level.

(*ii*) Utilising space to better advantage.

(*iii*) Increasing productivity.

(2) Waste Reduction by:

(*i*) Eliminating damage to material during handling.

(*ii*) Being flexible to meet specific handling requirements of different nature.

(*iii*) Making proper control over stock during in and out handling.

(3) Improve Productivity by:

(*i*) Increasing productivity per man-hour.

(*ii*) Increase in machine efficiency through reduction of machine down time.

(*iii*) Smoothing out workflow.

(*iv*) Improving production control.

(4) Improve Working Conditions by:

(*i*) Providing safe working conditions.

(*ii*) Reducing worker's fatigue.

(*iii*) Improving personal comfort.

(*iv*) Upgrading employees/workers to productive work.

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(5) Improve Distribution by:

(*i*) Decreasing damage to products during handling and shipping.

(*ii*) Improving routing.

(*iii*) Improving location of storage facilities.

(*iv*) Increasing the efficiency of shipping and receiving.

16.3.1 Advantages of Scientific Material Handling

1. Cost Reduction by:

(*a*) Decreasing the inventory costs.

(*b*) Utilizing the space to better extent.

(*c*) Increasing the overall production of the system.

2. Waste Reduction : This is achieved by:

(*a*) Maintaining proper control over in and out of stock handling.

(*b*) Eliminating damage to material during the handling process.

(*c*) Providing flexibility to meet the specific handling requirements of all materials.

3. In creased productive capacity: It is achieved by :

(*a*) Improving productivity per man-hour.

(*b*) Improving the efficiency of machines by reducing the machine down time.

(*c*) Smoothing out workflow in the plant.

(*d*) Improving the production control.

4. Improved working conditions: These are achieved by:

(*a*) Improving the personal comfort.

(*b*) Reducing fatigue of workers.

(*c*) Proving safer working conditions.

(*d*) Upgrading employees for productive work.

5. Improved distribution: It is achieved by:

(*a*) Improved routing.

(*b*) Improve location of storage facilities.

(*c*) Improving the efficiency of shipping and receiving.

(*d*) Reduction in damages of products during handling.

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16.3.2 Basic Requirements of Material Handling Equipments

The various requisites of materials handling euipments are as follows:

(*i*) It must be able to perform the basic function (storage and transportation) of material handling.

(*ii*) It must facilitate production planning, inspection and process control activities.

(*iii*) It should the able to reduce the work cycle time (total production cycle time) i.e. minimizing/reducing the unproductive material handling time.

(*iv*) It should improve the capacity utilization of the plant.

(*v*) It should minimize the work in process or the total inventory requirements.

(*vi*) It should be able to reduce the workers mental and physical fatigue. This factor will ultimately improve satisfaction and safety level of workers.

16.4 ENGINEERING AND ECONOMIC CONSIDERATIONS

According to George Hageman the important 'Engineering and Economic' factors related with materials handling installation can be considered under following heads:

16.4.1 Factors of Plant and Operating Techniques

The following questions are relevent under this head:

(*i*) Are the present Techniques of manufacturing/production, permanent or temporary ?

(*ii*) How long will the present buildings/structures remain an service ?

(*iii*) Is the general plant layout optimum for manufacturing and handling requirements ?

(*iv*) Is the sequence of operations are such which provides highest efficiency ?

(*v*) What processes/operations and departments must be tied together or clubbed into one ?

(*vi*) If trucks or floor type of equipments are to be used, are the aisles and passage ways sufficient for conveniences in handling speed, safety and non interference with production process ?

(*vii*) Are the floor levels smooth, made of corrosion resistant materials ? Will they withstand the expected loads during production ?

(*viii*) If overhead systems are utilized, if the building structure is strong enough to hold them and are the clearances ample for their installations ?

16.4.2 Factors Concerned with Material Handled

(*i*) Kinds or nature of materials or parts and components handled:

(*a*) Large or small.

(*b*) Bulk or parts.

(*c*) Heavy or light.

(*d*) Fragile or Rough tough.

(*e*) Shape (regular or odd shaped).

(*ii*) To be handled separately or in containers ?

(*iii*) Quantities to be handled.

(*iv*) If the flow is continous or intermittent.

(*v*) Distances over which transportation is required.

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16.4.3 Factors Concerned with Handling Equipment

(*i*) Type or Types of equipment suitable for the job under consideration

(*ii*) Capacity of equipment required.

(*iii*) Daily service hours requirement.

(*iv*) Size/specifications of the equipment.

(*v*) Space requirements for operation of handling equipment, (like aisles, passage ways for movement of trucks etc.).

(*vi*) Adaptability for other services for the objective.

(*vii*) Speed and ease of operation.

(*viii*) Power requirements of the equipment.

(*ix*) Durability and dependability of handling equipment.

(*x*) Relationship to other handling equipment in use or contemplated for future.

(*xi*) Auxiliary equipment which is required or economical to install for example loading platform etc.

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16.4.4 Economic or Cost Factors to be Considered

(*i*) Initial cost of the equipment required.
(*ii*) Cost of installation, rearrangement and alterations to utilize equipment and building etc.
(*iii*) Cost of repair and maintenance of the equipment used.
(*iv*) Cost of power/fuel required for operation.
(*v*) Rate of obsolescence of handling equipment.
(*vi*) Depreciation rate.
(*vii*) Probable salvage value of equipment at the end of its useful life.
(*viii*) Labour cost for operation of equipment.
(*ix*) Cost of necessary auxiliary equipment (such as chargers for batteries etc.).
(*x*) Interest on investment made for purchasing equipment.
(*xi*) Taxes and insurance charges on equipment procured.
(*xii*) License fees (for vehicles that may operate outside the factory or on highways).
(*xiii*) Rent charges for space needed for parking of vehicles.
(*xiv*) Cost of supervision of the equipment.
(*xv*) Increased production expected by use of handling equipment.
(*xvi*) Savings that the equipment shall bring about in direct labour cost or other allied costs.

16.5 PRINCIPLES OF MATERIAL HANDLING

A material handling system should be able to move and store the material effectively with minimum effort, maximum safety and in the shortest time. Following are some of the important guiding principles of economical handling:

(1) Using the principles of containerization, unit load or palletization, materials to be moved should be aggregated into a larger unit size and the unit size should be same for all materials. The materials are typically carried on a pallet or some other standard size container for convenience in handling. The materials and containers are known as unit load. So the load should be as large as possible/practical.

(2) Transport the full unit load whenever possible instead of practical loads. Load the material handling equipment to its maximum safe limit loading.

(3) Minimize the distances moved by adopting shortest distances possible. Generally the realization of this principle is layout design dependant.

(4) Follow the straight-line flow rule i.e. the material-handling path should be a straight line. This rule is consistent with the principle of shortest distance.

(5) Minimize the non-move of terminal times. The total time required for movement of material is sum of the actual move time and time taken in loading, unloading and other allied activities which do not involve actual transport of material.

(6) Utilize gravity principle for assisting the movement of materials wherever possible with due consideration to safety and risk of product damage.

(7) Follow the mechanization principle. Employ mechanical aids in place of manual labour in order to speed up material movement, increase the efficiency and economy of the system where possible.

(8) Integrate the materials handling system with the other system working in the enterprise including receiving, production, inspection, packaging, storage, warehousing and transportation etc.

(9) Integrate the material flow with the flow of information required for handling and storage systems. Such information for various items moved should include identification, picks point and destination point in order to improve the efficiency of the system.

(10) Changes in sequence of production operations may be suggested in order to minimize back tracking and duplicate handling.

(11) Effective, efficient, safe, standard, appropriate flexible and optimum sized material handling equipment should be selected.

(12) The handling equipment should not interfere with the production lines.

(13) Run conveyors overhead and stack load on top of each other or in racks as high as safety permits.

(14) Make accurate and complete analysis for installation, operation and maintenance cost of proposed devices (in case of suggested change).

(15) Provide right equipment at right time.

16.6 SELECTION OF MATERIAL HANDLING EQUIPMENTS

The usual production cycle consists more in moving the materials than converting them into final product. Hence sufficient attention must be given in fitting the internal transport (material handling arrangement) system in the manufacturing plant so as to constitute a single unit. If it is insufficient it may cause delays and decrease efficiency of the production system, which results in the increased cost of production. Hence this problem should be given due consideration and material handling equipment should be utilized unless it is quite sure that these will be cheaper than manual means of handling. The selection of material handling equipments depend upon the followings:

(1) Nature of the product & its perishability.
(2) Volume of production.
(3) Shape and size of products.
(4) Methods of production.
(5) Sequence of operations.
(6) The production rate of the industrial unit.
(7) Space availability and type of layout used.
(8) Number of times the materials are to be handled and distance to be covered.
(9) Possibility of future expansion if any in the plant.
(10) Power availability.
(11) Initial cost of installation, operation and maintenance costs.
(12) The location of assembly, testing beds.
(13) The availability and wages of unskilled labour.
(14) Depreciation costs.
(15) Design of material handling equipment its capacity, strength and rigidity.

It is clear from above that the selection of materials handling equipment depends on so many and it is difficult to make any recommendation without taking into consideraton the practical aspects of the problems.

16.7 SOLUTION OF MATERIAL HANDLING PROBLEM

The major problem concerning material handling in industry today is how to solve its handling problems and improve its handling techniques. The systematic procedure is as follows.

1. Approach the problem

(*a*) What to move ?
(*b*) Where to move it ?
(*c*) How to move it ?
(*d*) What equipment to use ?

2. Organise a programme for better handling

(*a*) Delegate responding for the function.
(*b*) Provide the necessary authority for the discharge of received.
(*c*) Ensure that periodic reports of progress are received.
(*d*) Evaluate the efficiency of the programme.

3. Calculate handling departments

(*a*) Cost of handling departments.
(*b*) Individual accounts chargeable to handling.
(*c*) Total cost to be shown as percentage of factory costs.

In fact, no universal answer can be given to all handling problems. Each problem can be considered on its own merits and each type of materials handling equipment should be used in its proper place. The most effective approach to materials handling problems is an analysis, if the situation demands it. A number of methods of Analysis are available to the materials handling engineer, who must be able to form, Structure and tools used is connection with them there are a number of elements common to all of them. The basic steps that should be followed in the analysis are:

1. Assemble pertinent data and information.
2. Identify each factor that will affect the analysis.
3. Ascertain relationship by graphs, diagrams etc.
4. Show this relationship by graphs, diagrams etc.
5. Select handling methods which may be used.

A good material handling programme if intelligently conceived and applied, should meet the following objectives:

1. Reduce handling cost:

(*a*) By way of reducing indirect labour cost and overhead
(*b*) By way of reducing transportation cost, as a whole (reduction in loading and receiving cost.
(*c*) By way of utilizing space to better advantage.
(*d*) By way of increasing productivity.
(*e*) By way of decreasing inventory costs.

2. Reduce waste:

(*a*) By way of maintaining safe handling, that is reduction in accidents.
(*b*) By way of eliminating damage of material in process and finished inventory during the handling process.
(*c*) By way of flexibility to meet the specific handling requirements of each material.
(*d*) By way of maintaining proper control over in and out of stock handling.

3. Increase productive capacity:

(*a*) By wayof increasing machine efficiency and production as whole through reduction of down time.

(b) By way of improving production control.

(c) By way of smoothing outwork flow in the plant, that is reducing work in process/ improved layout.

(d) By way of increasing productivity per man-hour.

(e) By way of increasing capacity of existing building.

4. **Improve working conditions:**

(a) By way of providing safer working conditions.

(b) By way of reducing worker fatigue.

(c) By way of upgrading employees to production work.

(d) By way of reducing aisle congestion.

(e) By way of improving personal comfort.

(f) By Increase in availability of product.

(g) By providing strategic location of storage facilities.

5. **Improve distribution:**

(a) By way of decreasing damage of products in handling and shipping.

(b) By way of improving routing.

(c) By way of increasing efficiency of shipping and receiving.

(d) By way of improving quality standard.

A good material handling programme can bring all these benefits to an industrial concern, provided it is well informed on the materials that are moved in the factory. A plan of the factory showing the movement of different materials, capacities of the Handling equipment (manual and mechanical) in use, the labour force employed in production work and in handling.

16.8 CLASSIFICATION OF MATERIAL HANDLING EQUIPMENT

The people responsible for determining what specific types of material handling equipment will be required and how many units of each type will be needed must start taking into consideration what is to be transported (i.e. materials), the rate at which the things are to be transported (i.e. speed-variable, fixed and either fixed or variable) the space through which it is to be transported (i.e. path to be followed and movement possible may be vertical, horizontal or combination of the two).

It is important to realize that at every stage from which or to which it becomes essential to transport/move something, there can be a number of alternative means of transportation which can be operated either manually or mechanically. So the person concerned or responsible for designing the material handling system for an organization must have an intimate knowledge about the operating characteristics of various types of equipment suitable for the purpose.

A wide range of materials handling and transporting equipment is available, which are suitable for most of the industrial requirements. Such equipments though costly prove very paying in the long run. They are helpful in following areas:

(1) Minimize the total handling period and hence cost.

(2) Handling becomes more easier, cleaner and safe.

(3) The idle time of workers and machines would be eliminated which would have been there while waiting for the materials for necessary operations.

(4) Would result in fast materials movements.

(5) Would decrease the workers fatigue.

(6) Would improve safety conditions.

(7) Can stock and locate the materials better and in lesser space.

(8) Automation can be adopted for improving production.

Handling can be classified as:

(1) Manual Handling.

(2) Mechanical Handling.

In this chapter we are mainly concerned with mechanical handling devices. There can be three major divisions of this type of handling such as:

I. Transportation Equipment or Devices. (For horizontal movement).

II. Lifting and Lowering Equipment or Devices. (For vertical movement).

III. Combination of Transportation and lifting plus lowering devices.

16.8.1 Transportation Equipment or Devices

These devices are useful only for horizontal movement of materials. These devices include trucks and other similar vehicles. These vehicles are powered by hand, gasoline or electric power and have the capability of transporting material and manpower in a horizontal direction. These also include variable path equipments and can be utilized so long as travelling surfaces are available and the route is obstruction free. Thus these vehicles occupy the space intermittently and as soon as the work is over the space is free for some other operation.

The simplest among these are wheel barrows and hand trucks. But these devices need large amount of manpower for relatively small load. These involve easy portability, greater flexibility and low cost. When movement from one workstation to other is required.

Tractors and trailers are the other popular modes of horizontal transportation.

Great flexibility is provided by these methods. Trailers can be left loaded and can be picked up later by other different tractors. This is considered as one of the most convenient and important methods of material handling inside the plant. Skids can be used with lift trucks. These are the improvements over wheel barrows and hand trucks. For horizontal transportation of commodities like natural gas, oil and water etc. pipelines and pumps can also be used. Figs. 16.1 to 16.32 show the various transportation devices used in this category.

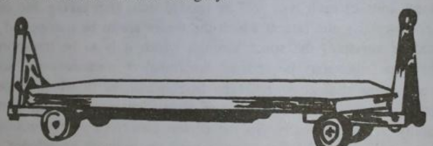

Fig. 16.1: Heavy duty both Side Turn Table Plateform Trailer with Solid Rubber Tyred Wheels

Fig. 16.2: Elevating Truck having a Rigid Steel Structured Frame

Fig. 16.3: Portable Hydraulic Stacker

Material handling contd.
from
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SCOPE OF MATERIAL HANDLING

MATERIAL HANDLING

Scope; Principles of economic material handling; objectives; classification of material handling equipments; Common hoisting equipment; Common conveying equipment; Selection of material handling equipment; Safely requirements; Workstation design.

6.1 SCOPE

Material handling includes all such movements from the receipt of raw materials to the shipment of finished goods. It is the art and science of packing, moving and storing of raw materials and components, work-in-progress and finished goods. The following are the areas of material handling:

1. Packing of raw materials and components at suppliers shops.
2. Loading and transport to the manufacturing plant.
3. Unloading at plant.
4. Receiving, storage and issue of material for production.
5. In-process handling.
6. In-process storage.
7. Work-place handling.
8. Intra-department handling and inter-department handling.
9. Warehousing of finished products.
10. Loading and transportation of product to customers/distributors/dealers place.

Material handling is an essential part of manufacturing activities and accounts for 20% to 50% of total production cost. Material handling can help reduction of costs, increase of productivity and improvement of cash flow. Mechanization of material handling can improve efficiency, increase production, reduce work-in-process and decrease damage to products at various stages of handling.

6.2 PRINCIPLES OF ECONOMIC MATERIAL HANDLING

The main principles of economic material handling are:

1. Minimize the total handling time.
2. Promote easier, safe and cleaner handling.

page1

3. Eliminate idle time of workers and machines.
4. Make material movements faster.
5. Decrease fatigue of the workers.
6. Increase safety.
7. Locate and stock materials in a better way and less space.
8. Automation of machines to increase production.

In the *selection of the material handling equipment*, the following costs should to considered:

(a) Capacity Outlay: This includes:

(i) Cost of equipment
(ii) Cost of erection
(iii) Cost of transportation
(iv) Cost of construction cost, civil and electrical.

The losses due to interest and depreciation on the above investement have to be taken into account.

(b) Operation Handling Cost: This includes:

(i) Cost of electric power.
(ii) Cost of repair and maintenance including spare parts.
(iii) Cost of lubricating, wiping, cleaning and consumables.
(iv) Wages and salaries of the personnel plus additional social services.

The American Society of Mechanical Engineers (ASME) has developed the following formulae for estimating the economics with the use of material handing equipment.

1. Maximum justifiable investment in material handling equipment:

$$Z = \frac{X(S+U+T-E)}{(A+B+C+D)}$$

where A = %age allowance on investment.
B = %age allowance for insurance and taxes.
C = %age allowance for maintenance.
D = %age allowance for depreciation.
E = Annual cost of power, supplies, etc.
S = Yearly saving in direct labour cost (Rs).
U = Yearly earnings through increased production (Rs).
T = Yearly savings in fixed and operating charges (Rs)
I = Initial equipment cost (Rs).
X = Percentage of time of the year during which the equipment is used.

2. The yearly cost of maintenance can be estimated as

$$Y = I\,(A + B + C + D)$$

3. Yearly profit from the operation of the equipment above the simple interest

$$V = X(S + U + T - E) - Y$$

4. Estimated rate of profit

$$P = \frac{V}{I} + A$$

5. Number of years required for amortization of investments out of earning,

$$H = \frac{100}{P+D}.$$

6.3 OBJECTIVES

The design, cost and operation of material handling system depend upon the objectives of material handling. The main objectives of material handling are as follows:

1. Reduction in handling: It can be achieve by
   (*i*) Process changes
   (*ii*) Layout improvement
   (*iii*) Increased size of units handled
   (*iv*) Use of proper equipment
2. Reduction in time: It can be achieved by
   (*i*) Reducing waiting time
   (*ii*) Loading/unloading time
   (*iii*) Handling time
3. Principle of *Unit Load*. Optimum number of pieces be moved as one lot or minimize handling and maximize equipment utilization.
4. Use of *gravity* as source of *motive power*.
5. *Safety:* Safe and effective equipment to be used.
6. *Use of containers:* Containers/pallets/drums should be used to reduce cost of handling/and damage during transit.
7. *Standby facility* should be maintained which can be used in the event of sudden breakdown of normal equipment.
8. Periodic checking, repairing and maintenance of material handling equipment should be carried out.
9. Avoid interference with production line.
10. *Flexibility:* Material handing equipment services should be evaluated periodically and necessary change should be incorporated whenever it is possible.

6.4 CLASSIFICATION OF MATERIAL HANDLING EQUIPMENT

Material handling equipments can be classified as:

1. *Hoisting devices:* Lifting and lowering vertically.
2. *Conveying equipment:* Transportation horizontally.
3. *Combination devices:*

Some of these devices are listed in Table 6.1.

Material Handling Equipments

Hoisting Devices	Conveying Equipment	Combination
1. Block and tackle	1. Wheel barrows	1. Chutes/slides
2. Hand and power wrinches.	2. Hand and power trucks	2. Hoists and trolleys on overhead rails.
3. Hoists	3. Industrial narrow railways for heavy goods	3. Forklift trucks
4. Elevators	4. Tractors and Trailors	4. Crane trucks
5. Pillar crane bridge	5. Pipelines	5. Conveyors
6. Overhead bridge crane	6. Pumps for oil, gas and water, etc.	6. Spiral chutes
	7. Aerial tramsways supported from top.	7. Spiral rollers
		8. Cranes

6.5 COMMON HOISTING EQUIPMENT

6.5.1 Fork Lift Truck

These are used to lift and transport packed (Pallet) loads horizontally, path can be variable, speed variable, driven electrically or by I.C. Engine.

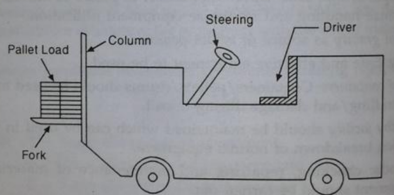


Fig. 6.1. Fork Lift Truck.

The forks are attached to vertical column or guide on the trucks. Forks can be lifted to desired height along with the material (boxes, etc.) on them and material can be stocked at the proper place, even very close to roof. These are used for short distances (40 to 70 meters) travel and find indoor applications normally.

The following precautions are to be taken in its operation:

1. The operators limbs should be kept away from dangerous parts such as slides or platforms.
2. Battery mountings behind the driver should be properly secured to withstand impact of deceleration and overturning of truck.
3. A periodical check of brakes, steering apparatus and lift mechanism should be carried out.
4. It should not be driven over objects lying on the floor.

5. When the truck is without load, the forks should be kept 200 mm above ground.
6. Truck routes and crossings be clearly marked.
7. Mirrors should be provided at blind corners and obstacles should be marked in black and yellow diagonals.

6.5.2 Cranes

These are used for lifting and lowering bulky items and packages or cases. They find application in heavy engineering and generally in intermittent type of production. They provide overhead movements. The common cranes are mobile motor cranes, overhead cranes, travelling bridge cranes, derrick cranes.

1. Overhead Bridge Crane

It is an overhead travelling crane and is very popular in most industries manufacturing engines, compressors, pressure vessels, foundries, steel mills, etc. An I-Beam is mounted on rollers which can travel on building columns in Z-direction. A trolley is mounted on the eye with hoist.

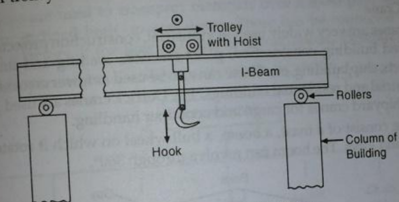


Fig. 6.2. Overhead Bridge Crane

The trolley can move in X-direction. The hook can move in Y-direction.

The following safety precautions should be taken in design and operations:

1. The maintenance personnel who may be invisible from control room should be safeguarded.
2. The standing button and operating levers should have the provision of locking.
3. Cranes should be operated at least 3 m away from high voltage overhead wires.
4. Automation of feeding mechanism can ensure safety of the worker.
5. Sudden lifting and panic braking should be avoided.
6. A signal man should guide the crane operator when he cannot see the load parts and path clearly.
7. Wire ropes should be checked daily. The broken strands should be replaced.
8. The load should be lowered on the ground when crane is stopped.

2. Jib Crane

The hook of jib crane can move in a circle. This type of crane is preferred where lifting of jobs is required in a few locations or where bridge crane cannot be erected. The jib crane can be erected outside near the wall of a building.

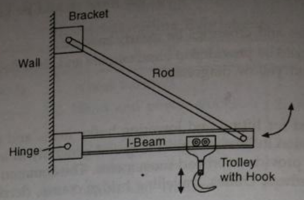


Fig. 6.3. Jib Crane

The hoist unit is mounted on an I-section which is supported on a column or wall.

Note: A gantry crane can act as an auxiliary to a bridge crane.

3. Derrick Crane

These cranes are very widely used in industrial, construction projects especially multi-storeyed building construction, plant erection, loading and unloading of cargoes at ports, ship building, etc. These can also be used as tower cranes for erection of high industrial and residential buildings. The Derrick cranes are used port tower cranes and shipyard cranes for cargo and container handling.

The crane consist of a mast, a boom, a bull wheel on which it rotates about a vertical axis and guys. The boom can revolve through 360°.

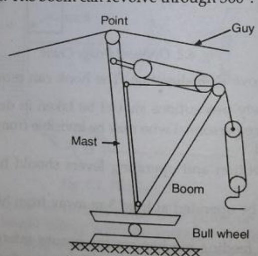


Fig. 6.4. Derrick Crane.

4. Mobile Motor Cranes

Mobile motor cranes have four motions viz, hoisting, derricking, slewing and travelling which is an extra motion as compared to Derrick cranes. The mobile cranes can be mounted on a crawler, truck or rails.

(*i*) Crawler mounted cranes are highly maneourable and have the ability to operate on unmade ground. Therefore these are used in rough terrain.

(*ii*) Truck mounted cranes have high mobility and can travel upto 75 kmph on good roads.

(iii) Rail-mounted cranes move on rail tracks and are used in steel industry, dockyards and railways.

The mobile cranes can be driven by diesel engines or by electricity.

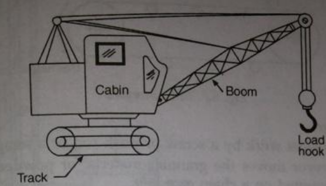


Fig. 6.5. Crawler Crane.

6.5.3 Conveying Equipment

The conveyors are used to transport materials over a fixed path which may be horizontal or inclined both up and down. These can be connected to different locations in a factory. If the flow of material is continuous, these are economical.

The conveyor can be classified as shown in figure 6.6.

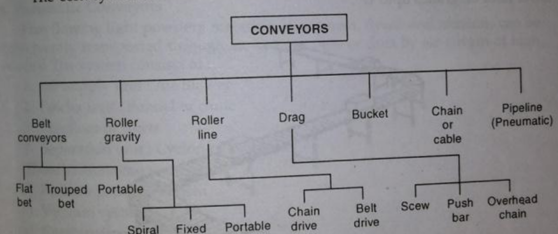


Fig. 6.6. Classification of Conveyors.

1. Belt Conveyors

The belt may be flat or trough shape to hold granular material to avoid slippage. The belt material may be rubber, covered canvas, steel, plain fabric or woven wire. A fixed conveyor is used in a mass production shop. Portable conveyors are used in intermittent job like unloading of a freight car.

2. Roller Conveyors

These conveyors can be gravity aided or powered to transport products with flat buttoms. The small items are put in boxes, tins or pallets and big items can be directly loaded on the rollers. The roller conveyors can travel in straight path or curved path.

Gravity conveyor are easy to install and are preferred in operation. Packages of hosiery goods, steel sheets, etc., can be transferred using gravity conveyors.

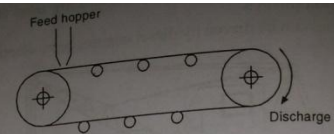


Fig. 6.7. Belt conveyors.

3. Other Conveyors

The drag conveyors work by a screw or push rod or a scrapper.

A bucket conveyor moves the granular material or powder or liquid. The buckets may be mounted on a chain or a belt.

Pipeline conveyors are used for transporting wheat or salt or pulverized material through the pipes pneumerically.

4. Gravity Roller Conveyor

This is a package conveyor and used to transport various shapes and sizes of boxes which extended over several rollers. The rollers are supported in frames and are driven by gravity. These can move boxes horizontally or from upper floor to lower floor on grades upto 17°.

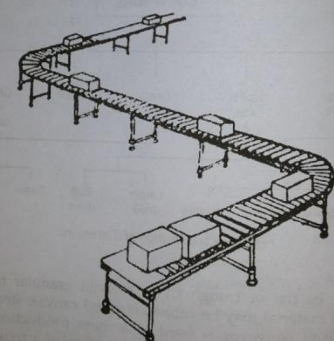


Fig. 6.8. Roller Conveyor.

5. Screw Conveyors

These are used to move materials over a trough by a rotating screw. The screw can be helical spiral, ribbon spiral or cut flights. Screw conveyors are widely used for dusty or hot loads. These can be used for handling products, food products, pulverized coals and other granular materials.

Screw conveyors easily negotiate rising gradients and can operate vertically ligting materials upto 15 m.

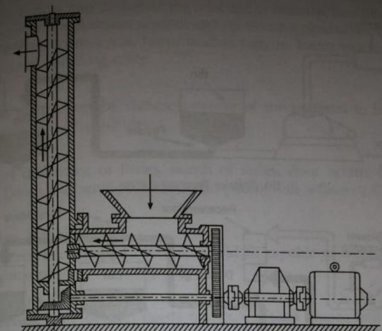


Fig. 6.9. Vertical screw conveyor with a screw feeder.

6. Pneumatic Conveyors

Free flowing light powdery materials like cement, flyash and minerals can be conveniently transported through an air tight pipe or duct by air stream of high velocity. The system consists of :

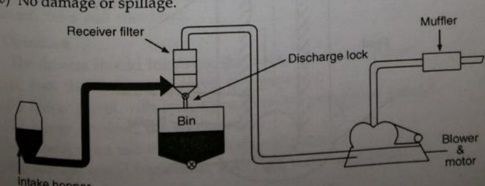
1. Air supply unit : Air Blower
2. Feeder unit : Funnel or chute
3. Pipelines or ducts
4. Separation unit : Cyclone separators

These systems can work as :

(*i*) Positive pressure system
(*ii*) Vacuum system
(*iii*) Combination system

These systems have the following attractions :

(*i*) Saving in cost of bags and packages.
(*ii*) Less expensive in bulk handling.
(*iii*) Lesser labour cost.
(*iv*) No damage or spillage.



(a) Negative Pressure (vacuum) system.

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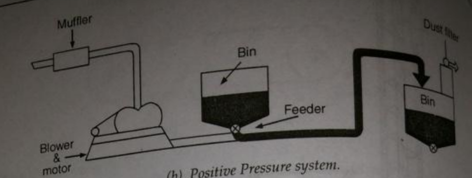
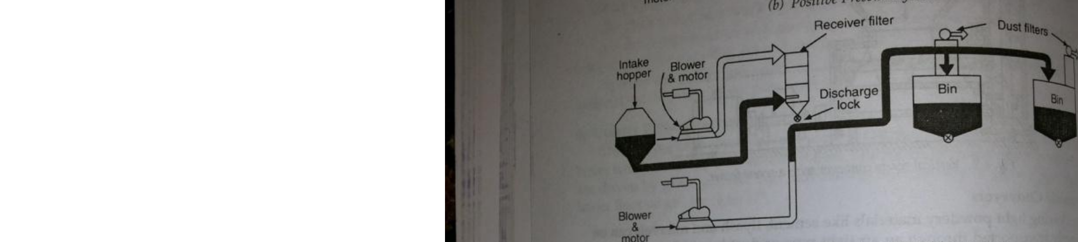


(b) Positive Pressure system.



(c) Combination of Negative and Positive pressure.

Fig. 6.10. Types of Pneumatic conveyors

7. Bucket Conveyors and Elevators

These are used for transporting dry granular materials in the vertical directi with the help of buckets and trays. These are of two types.

(i) *Chain bucket elevators.* Bucket are attached to chains which move on whee

(ii) *Bolt bucket elevators.* Buckets are attached to belts moving on pulleys.

It consists of an endless chain or belt attached to buckets and move in a she metal casing. The material is fed at the bottom and unloaded at the top. These a widely used to handle coal, chemicals, cement etc.

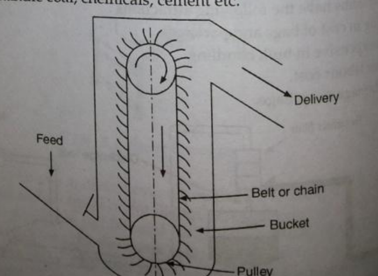
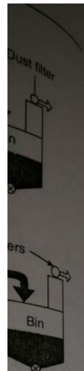


Fig. 6.11. Bucket Elevator.



rtical direction
ove on wheels
pulleys.
nove in a sheet
top. These are

6.6 SELECTION OF MATERIAL HANDLING EQUIPMENT

The following factors may influence the selection of material handling equipment. The best equipment will ensure smooth and continuous production flow, accident free, reduced production cycle, lesser worker fatigue, better working conditions and less material handling costs.

1. Material

The size, shape, weight, delicacy, nature of the material to be moved will dictate the selection of machines.

2. Plant Layout

The level difference of floors, width of aisles, door width, ceiling height, strength of floors and walls, columns and pillars will influence the selection of machines.

3. Production Machines

The material handling equipment should be capable of handling the output from a machine of maximum capacity.

4. Material Flow Pattern

A horizontal flow pattern needs trucks, ovehead cranes and conveyors. A vertical flow pattern needs elevators, pipes and conveyors.

5. Production System

The type of production system will affect the selection of material handling system.

For example, conveyors are more suitable for mass production and powered trucks for batch production.

6. Capital cost of material handling equipments.

7. Operating cost.

8. Life of the equipment.

9. Repair and maintenance equipments.

6.7 SAFETY REQUIREMENTS

The accidents in factories can be reduced by proper selection and operation of material handling equipment. The following five point programme should be followed to ensure safe operation.

1. Design

The machine design should ensure adequate clearances, easy installation and maintenance of the system. All machines and systems should be designed as per relevant codes and standards.

2. Operation

The drivers should following the instruction given below:

(*i*) Face the direction of travel of equipment.
(*ii*) Never travel with fork, more than 200 mm above ground.
(*iii*) Never overload the equipment.
(*iv*) Always put red flags on overhanging loads.
(*v*) Always travel backwards with high and bulky loads.

In addition to above space provisions, the following factors are considered in the design of workstation.

1. Easy access to safety stops in case of emergency.
2. Easy access to the machines for lubrication, cleaning, maintenance and repair work.
3. Convenience of foundation and machine installation.
4. Aisle space between machines.
5. Appropriate lighting, ventilation and safety arrangements.
6. Requirements of Factory Act, 1948.

SUMMARY

Material handling is the art and science of moving materials from receipt of raw materials to dispatch of finished goods. It is an essential part of manufacturing activity and may account for 20% to 50% of product cost. In selection of material handling equipment both capital outlay and operation handling cost should be reduced. Fork lift truck, cranes, belt and roller conveyors are the most common material handling equipment and their selection aims at reduction in production cost and production cycle. Safety requirements can be met by proper design, operation and testing of equipment, and training and incentive scheme for the drivers. Work station design determines the production efficiency and accuracy of the operation. It has to be designed to meet the requirements of Factory Act, 1948.

THEORY QUESTIONS

1. Discuss the safety measures adopted while using material handling equipment.
2. What are the main material handling equipments ? How is a material handling equipment selected for a particular requirement ?
3. Explain material handling equipment selection.
4. Explain the factors considered in designing a work station.
5. What is the scope of material handling in a manufacturing plant ?
6. Discuss the principles of economic material handling.

OBJECTIVE TYPE QUESTIONS

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Fill in the Blanks:

1. Various types of conveyors are.................
(Belt, roller, chains, bucket, screw and pipe line conveyors)
2. Two main functions of material handling are ....
(to assist plant layout and reduce production cost)
3. Art of moving, packing, storing materials is called .... (material handling)
4. Factors considered for selecting material handling equipment are ....
(overhead cranes)

Q. Relationship B/W Plant layout & Material handling

16.9 RELATION BETWEEN PLANT LAYOUT AND MATERIAL HANDLING

There is a close relationship between plant layout and material handling. The material handling technique to be used definitely effects the plant layout and the factory building. A sound low cost method can be designed and installed only if material handling is considered an integral part of plant layout.

A well considered arrangement of production equipment, the proper location of different departments, a logical sequence of operation within the department and convenient location of store areas, tool cribs and similar activity centres is required for a good material handling arrangement. The efficient and economical material handling system can-be designed and selected for installations only after the floor plan has been adequately organized.

In all types of plant layout provisions for the receiving and shipping of materials by various possible means (like trucks or train etc.) should be made. If it is required to move the materials by hand operated or power operated trucks, sufficient passage should be provided.

If the building is multi-storeyed, lift, elevators and conveyors of different types must be utilized to enable efficient material handling.

The location of items in the storeroom should provide for minimum handling of materials to the jpoipt of issue, accessibility and efficient space utilization.

16.9.1 Material Handling in Product Type of Layout

...direct means of transportation between various operations. ...special purpose in nature for

Write notes on

(i) Principle of unit load

(ii) concept of Containerization & Palletization

Fig. 2.116.

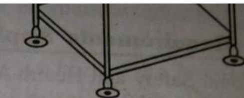


Fig. 2.117.

Posts. Members either fixed or detachable, positioned vertically on a pallet to take the weight of superimposed pallets (See Fig. 2.116).

Post Pallet. Pallet having a superstructure of posts, with or without rails (See Fig. 2.117).

2.3.13. Principle of Unit Load and Concept of Containerization and Palletization

It is easier and faster to move hundred small parts say castings or cardboard sheets by grouping them in one unit than moving them individually one by one. This principle of unit load can also be explained like this. If the bearer of a hotel removes cups, plates and other crockery from a table by placing them in a tray, it is called material handling by unit loads. Definitely, he would have spent much more time and efforts in removing all the crockery by one cup or one plate at a time.

By using available machines (like one for strapping steel strips around cotton bales), fork lift trucks, skids and pallets (see Fig. 2.118), it is easy to handle materials in unit loads and stack them neatly and proprely (even as high as the ceiling) thereby reducing the storage space requirements.

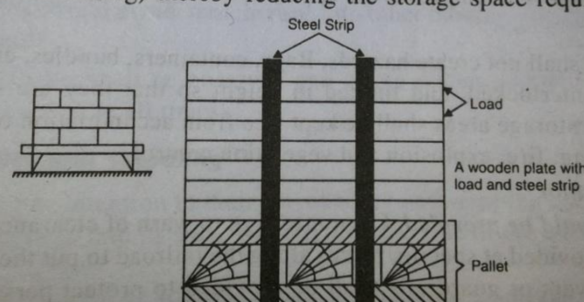


Fig. 2.118. Skid and Pallet.

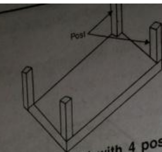


Fig. 2.119. Pallet with 4 posts.

Fig. 2.120. Wire mesh box

Depending upon the types of items to be transferred, a suitable pallet can be designed. Fo items irregular in shape and liable to be damaged by crushing, utilize a post pallet (see Fig. 2.1 small jobs can be placed in wire mesh box (See Fig. 2.120).

Containerization uses principle of unit load. In this system, big metal containers have number of small products filled in them. These containers are placed on the truck or in the trailers which are pulled by tractors or trucks. Afterwards, the containers can be loaded on railway trailers and can be taken to places from where, with the help of cranes, they can be shipped. Items like refrigerators, air-conditioners or television sets can be sent to distant places using the principle of containerization. The system is much safer and involves a lot of saving. (Fig. 1.121)

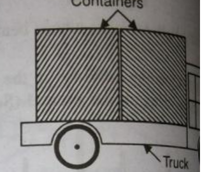


Fig. 2.121. Truck with co

2.3.14. Safety Requirements Applied to Material Handling

The Occupational Safety and Health Administration have developed safety requirements for a of activities in industries and many Governments have enforced these safety requirements in regulations. These requirements also affect many material handling activities, and some of the examined.

Page15

Regarding Material Handling and Storage

(1) *Use of Mechanical Equipment*

When and wherever mechanical handling equipment is used, sufficient safe cleara allowed for aisles, at loading through doorways, and curved passage. So the passageways must be kept clear and in good condition with no obstruction of any so create hazard.

It is both necessary by law and advisable from the standpoint of efficiency to clearly m factories or warehouses wherever mechanical equipment such as fork lift trucks, tow tractor-trailors, etc. are used. The primary aim *is the safety to personnel an psychological reasons*. This improves the appearance and morale and also productivit

(2) *Use of Storage*

Storage of material shall not create hazards. Bags, containers, bundles, etc. strored in t stacked, blocked, interlocked, and limited in height so that they are stable and se sliding or collapse. Storage areas shall be kept free from accumulation of materials th hazards from tripping, fire, explosion and vegetation control.

(3) *Provisions on the Floor*

Proper *drainage should be provided*. Clearance sign to warn of clearance limits shall b Blocks should be provided at specific places along the railroad to put the derailed rollin on the railroad. Covers or guardrails shall be provi open pit, tank and ditches, etc.

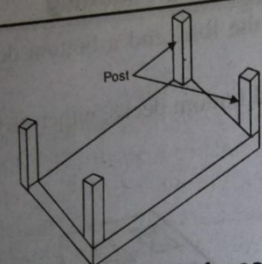
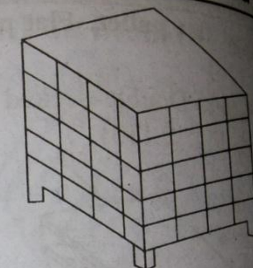


Fig. 2.119. Pallet with 4 posts.



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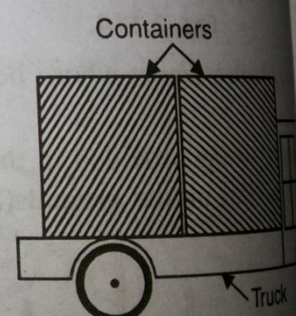


Fig. 2.121. Truck with co

2.3.14. Safety Requirements Applied to Material Handling

The Occupational Safety and Health Administr... of activities in indu...

MINIMAX LOCATIONAL PROBLEM

{Dated Fri 7-oct 2016} (P1)

Consider that there are 'm' existing facilities which are located at points (a_1, b_1) (a_2, b_2) (a_3, b_3) ----- ...(a_i, b_i) --- (a_m, b_m). So (a_i, b_i) is a existing location of ith existing facilities.

Let $f_i(x,y)$ is the distance B/w the existing facilities i and the new facilities.

$$f_i(x,y) \longrightarrow |x-a_i| + |y-b_i|$$

$f_{max}(x,y)$ is the max distance B/w the existing facility and the new facility.

$$f_{max}(x,y) \longrightarrow \max_{1 \le i \le m} \left\{ [x-a_i] + [y-b_i] \right\}$$

Step 1 :→ Calculate c_1, c_2, c_3, c_4 and c_5, where

$$c_1 = \underset{1 \le i \le m}{\text{minimum}} (a_i + b_i)$$

max. $$c_2 = \underset{1 \le i \le m}{\text{maximum}} (a_i + b_i)$$

$$c_3 = \underset{1 \le i \le m}{\text{minimum}} (-a_i + b_i)$$

$$c_4 = \underset{1 \le i \le m}{\text{maximum}} (-a_i + b_i)$$

and $$c_5 = \max_{1 \le i \le m} \{ [c_2 - c_1], [c_4 - c_3] \}$$

Step 2 :→ Calculate points P_1 & P_2

where, $P_1 = \left\{ \frac{1}{2}(c_1 - c_3), \frac{1}{2}(c_1 + c_3 + c_5) \right\}$

$P_2 = \left\{ \frac{1}{2}(c_2 - c_4), \frac{1}{2}(c_2 + c_4 - c_5) \right\}$.

Example 1:

In a foundry their are seven shops whose coordinates are summerised in a following table.

S.NO	Existing facilities	Coordinates of centeriod	
1.	Sand plant	10, 20	(a_1, b_1)
2.	Moulding shop	30, 40	(a_2, b_2)
3.	Pattern shop.	10, 120	(a_3, b_3)
4.	Melting shop	10, 60	(a_4, b_4)
5.	Fitting shop.	30, 100	(a_5, b_5)
6.	Annealing shop	30, 190	(a_6, b_6)
7.	Gauging shop	20, 190	(a_7, b_7)

The Company is intersected in locating a new costly fire fighting equipment in foundry. determine maximum location for the ~~so~~ new equipment.

Sol. see page 3.

Sol :→

$$C_1 = \min_{1 \le i \le m} (a_i + b_i)$$

$$C_1 = 10 + 20 = 30$$

$$C_2 = \max_{1 \le i \le m} (a_i + b_i)$$

$$C_2 = 30 + 190 = 220$$

$$C_3 = \min_{1 \le i \le m} (-a_i + b_i)$$

$$= -10 + 20$$

$$C_3 = 10$$

$$C_4 = \max_{1 \le i \le m} (-a_i + b_i)$$

$$= -30 + 190$$

$$= 160$$

$$C_5 = \max_{1 \le i \le m} \{ [C_2 - C_1], [C_4 - C_3) \}$$

$$= \max \{ (220 - 30), (160 - 10) \}$$

$$= \max \{ 190, 150 \}$$

$$C_5 = 190$$

Points P_1 & P_2

$$P_1 = \{ \tfrac{1}{2} (C_1 - C_3), \tfrac{1}{2} (C_1 + C_3 + C_5) \}$$

$$= \{ \tfrac{1}{2} (30 - 10), \tfrac{1}{2} (30 + 10 + 190) \}.$$

$$= \{ \tfrac{1}{2} (20), \tfrac{1}{2} (230) \}$$

$$P_1 = \{ 10, 115 \}$$

Contd from P-3

$$P_2 = \left\{ \tfrac{1}{2}(C_2 - C_4),\ \tfrac{1}{2}(C_2 + C_4 - C_5) \right\}.$$

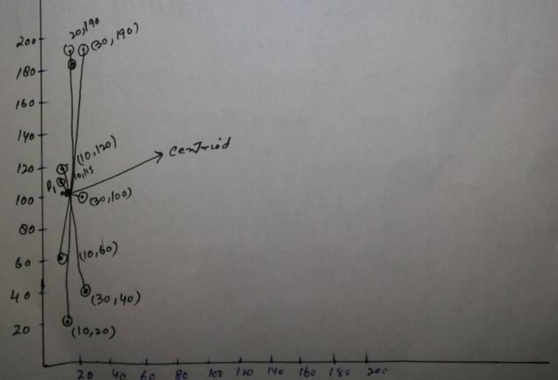
$$= \left\{ \tfrac{1}{2}(220 - 160),\ \tfrac{1}{2}(220 + 160 - 190) \right\}.$$

$$= \left\{ \tfrac{1}{2}(60),\ \tfrac{1}{2}(190) \right\}.$$

$$\boxed{P_2 = (30, 95)}$$

Graph paper needed.

{show on graph paper}



Square Equilidian Location problem
OR
GRAVITY LOCATION PROBLEM

If (P, q) and (r, s) are the Coordinates of the two locations then the Square equilidian location distance B/w the two points is
$(P-r)^2 + (q-s)^2$

Let a_i be the x-coordinates of existing facilities "i" and 'b_i' be the y-coordinates of existing facility "i"

x = coordinates of new-facility
y = coordinates of new facility
w_i the weights associated with the existing facility "i".
m = total no of existing facilities

$$f(x,y) = \sum_{i=1}^{m} w_i \left[(x-a_i)^2 + (y-b_i)^2\right] \quad (1)$$

Differentiating partially eq (1) w.r.to x.

$$0 = \sum_{i=1}^{m} w_i \left[2(x-a_i)\right]$$

$$0 = x\,2\,w_i - 2\sum_{i=1}^{m} w_i a_i$$

$$x = \frac{\sum_{i=1}^{m} w_i a_i}{\sum w_i}$$

$$\boxed{x^* = \frac{\sum_{i=1}^{m} w_i a_i}{w_i}}$$

$$x^* = \frac{\sum_{i=1}^{m} w_i a_i}{\sum_{i=1}^{m} w_i}$$

Again Differentiating Partially eq ①
w.r.to y.

$$\frac{\partial (y)}{\partial y} = \sum_{i=1}^{m} w_i\, 2(y - b_i)$$

$$0 = \sum_{i=1}^{m} w_i\, 2y - \sum_{i=1}^{m} w_i\, 2b_i$$

$$y = \frac{\cancel{2} \sum_{i=1}^{m} w_i}{\cancel{2} \sum_{i=1}^{m} w_i}$$

$$\boxed{y^* = \frac{\sum_{i=1}^{m} w_i b_i}{\sum_{i=1}^{m} w_i}}$$

ECONOMIC ANALYSIS

Different approaches are used for evaluating relative work of worth of alternative investment projects which include both qualitative analysis may recognise non-monitering factors like Social benefits, Safety, flexibility & the like in the evaluation of capital proposals. Quantitative analysis determines worth of investment project on the basis of monitering income tax, etc.

PAY BACK METHOD :→

Pay back period is equal to cost of investment divided by annual cash inflowse

$$= \frac{\text{cost of investment}}{\text{annual cash inflows}}$$

Example

Assume that investment (Project cost of Rs 40000 is expected to produce annual return (cash inflows) of Rs 50000 for 10 years, No salvage value recovery is expected from the investment at the End of 10 years. The initial investment will be recovered in 8 years.

$$= \frac{40000}{50000} = 8 \text{ years.}$$

Average Rate of Return:

i) Average rate of return on Original investment

$$ARR = \frac{\text{Average annual earnings}}{\text{total investment}} \times 100$$

Example:→ A project which costs Rs 120000 is expected to yield total earning of a depreciation and tax of Rs 60,000 over 3 years. The scrap value of the projects after 3 years has been calculated as 20 thousand. Calculate average rate of return on Average investment.

= Average earnings (after depriciation and tax = Rs $\frac{60000}{3}$

total investment in the project

$= 120{,}000 - 20000$

$= 100000$.

$\therefore ARR = \frac{20000}{100000} \times 100$

$\therefore ARR = 20\%$

ii) Average rate of return on average investment

$$ARR = \frac{\text{Average - annual earning}}{\text{Avg investment}}$$

Example :->

Calculate the average rate of return on average investment by using previous (examples) data.

Average annual earnings
= 20,000

Average investment = $\dfrac{\text{Original investment + Scrap value}}{2}$

$= \dfrac{1200000 + 20000}{2}$

$= 70,000.$

ARR = $\dfrac{\text{average annual earning}}{\text{Avag. investment}}$

$= \dfrac{20000}{70000} \times 100$

$= 28.6\%$

Profitability index :->

$= \dfrac{\text{Present value of cash inflows}}{\text{Present value of Cash out flowse}}$

Example :-> A project requires initial investment of Rs 85000 and is expected to give cash inflowse of Rs 10000, Rs 25000, and 10000, Rs 25000, and Rs 40000 for 5 years. The profit has a Salvage value of Rs 10000. The Companies target rate of return is 10. Calculate the profitability of the project by using profitability index

See P-10

P_10

Year	Cash inflows	Present value factor at 10%	Present value of cash in Rs. in Rs.
1	18,000	0.909	16362
2	25,000	0.826	20650
3	10,000	0.751	7510
4	25,000	0.683	17075
5	40,000	0.621	24840
			86437

Present value of cash inflows = 86,437.

Present value of cash out flows = 85,000

$\therefore$ Profitability index

$$= \frac{86437}{85,000} = 1.016.$$

which means net present value is +ve.

$\therefore$ Project is desirable.

—o—

A company is considering an investment proposal to install a new milling controls at a cost of 50,000. The facility has a lab life expectoming 5 yrs & no salvage value. The tax rate is 35%. Assume the firm uses the straight line depreciation & the same is allowed for tax purpose. The estimated cash flow before depreciation and tax from the investment proposal are as follows.

CFBT → cash flow before tax.

Year	CFBT (Rs)
1.	10,000
2.	10,692.
3.	12,769.
4.	13,462.
5.	20,385

compute i) Pay back period.
ii) Average rate of return.
iii) Internal rate of return.
iv) Net present value. at the 10% discount rate.

v) profit-ability index.

I Year	II CFBT(Rs)	III Depreciation	IV Profit	V Tax = 0.35 × profit	VI Earning of Tax (Profit − Tax)	VII Cash flow After Tax (Depression + Earning of Tax)	
1.	10000	10,000	—	Nil	Nil	10,000	10,000
2.	10,692	10,000	692	242.2	450	10,460	20,450
3.	12,769	10000	2769	969.15	1800	11800	32,250
4.	13,462	10000	3462	1211.7	2250	12250	44,500
5	20,385	10000	10,385	3634.7	6750	16750	61,250

11250

50000 − 44,500 = 5500.

i) Pay back period.

~~CAFT of 4 yrs~~ = 44500.

= 4 year + fraction of 5th yr

$= 4 + \frac{5500}{16750} = 4.32$ years.

ii) Average rate of return

$= \frac{\text{Average earning}}{\text{Average Investment}}$

Average Invest = Salvage value + $\frac{1}{2}$(investment − Salvage value)

$= 0 + \frac{1}{2}(50000)$

$= 25000.$

∴ Avg rate of return $= \frac{2250}{25000}$

$= 9\%$

iii)

$$NPV = -I + \frac{Cf_1}{(1+r)^1} + \frac{Cf_2}{(1+r)^2} + \frac{Cf_3}{(1+r)^3} + \frac{Cf_4}{(1+r)^4} + \frac{Cf_5}{(1+r)^5}$$

$$I = \frac{Cf_1}{(1+r)^1} + \frac{Cf_2}{(1+r)^2} + \frac{Cf_2}{(1+r)^3} + \ldots$$

$$\cancel{50000 = \frac{10,000}{(1+r)^1} + \frac{10,692}{(1+r)^2} + \frac{12769}{(1+r)^4}}$$

$$50000 = \frac{10,000}{(1+r)^1} + \frac{10,450}{(1+r)^2} + \frac{11800}{(1+r)^3} + \frac{12,250}{(1+r)^4}$$

$$+ \frac{16750}{(1+r)^5}$$

$$80000 = \boxed{r = 6\%}$$

(v) Net present value at the 10% discount rate.

Year	CFAT	Present value factor	
1.	10,000	0.90	9000
2.	10,450	0.826	8632
3.	11,800	0.75	8850
4.	12,250	0.68	8330
5.	16,750	0.62	10385
			45197

Net present value.

② Prof. index = $\frac{45197}{50000}$ = 0.903 Ans.

will observe that all the assignment are not fully made, and row R_4 will not have any assignment.

Example 23. Four different jobs can be done on four different machines. The setup and take down time costs are assumed to be prohibitively high for changeovers. The matrix below gives the cost in rupees of producing job *i* on machine *j*.

	M_1	M_2	M_3	M_4
J_1	5	7	11	6
J_2	8	5	9	6
J_3	4	7	10	7
J_4	10	4	8	3

How should the jobs be assigned to the various machines so that the total cost is minimised ?

[Patna Univ. B.E. (Mech.) 2002; Anantpur M.Sc. Math 1990]

Solution. Choose smallest element in each row and subtract it from all the elements of the row. Table 11.19.

Now column 3 does not have a zero. So choose the smallest element in the column and subtract it from all the elements of the column.

The resultant matrix is Table 11.20.

Row 1 has 0 in column 1, mark it $\boxed{0}$ and cross other zero in the 1st column by x showing that it cannot be used for making other assignments. (Table 11.20).

Row 2 has 0 in 2nd and 3rd column. Enrectangle 1st zero and cross the 2nd zero.

Table 11.19

$$
\begin{array}{c}
\\ J_1 \\ J_2 \\ J_3 \\ J_4
\end{array}
\begin{array}{c}
\begin{array}{cccc} M_1 & M_2 & M_3 & M_4 \end{array} \\
\begin{bmatrix}
5-5=0 & 7-5=2 & 11-5=6 & 6-5=1 \\
8-5=3 & 5-5=0 & 9-5=4 & 6-5=1 \\
4-4=0 & 7-4=3 & 10-4=6 & 7-4=3 \\
10-3=7 & 4-3=1 & 8-3=5 & 3-3=0
\end{bmatrix}
\end{array}
$$

Now Row 3 does not have zero. Row 4 has one unmarked zero in the 4th column. Enrectangle it. We see that row 3 and column 3 are without assignments. Hence we proceed to find minimum number of lines crossing all zeros.

Qr

Table 11.20

$\boxed{0}$	2	2	1
3	$\boxed{0}$	$\boxed{0}$	1
$\cancel{0}$	3	2	3
7	1	1	$\boxed{0}$

Table 11.21

$\boxed{0}$	2	2	1
3	$\boxed{0}$	$\boxed{0}$	1
$\cancel{0}$	3	2	3
7	1	1	$\boxed{0}$

No. of such lines = 3 which is less than n ($n = 4$), the order of cost matrix, hence optimal solution has not reached. (Table 11.21)

To increase the minimum number of lines we generate new zeros in the modified matrix. √ marks show action to be taken in the row or column. Examine the elements that do not have a line through them. Select the smallest element (here it is 1) and subtract it from all the elements that do not have a line through them.

Add this element to every element that lies at the intersection of two lines. Leave other elements untouched. The new matrix is in Table 11.22. Check for optimality. We see still minimum 3 lines will cross all the zeros of the matrix. Hence still optimal solution has not reached. We will have to create more zeros. √ marks show action to be taken in the row or column.

Table 11.22

0	2 – 1 = 1	2 – 1 = 1	1 – 1 = 0	√
3 + 1 = 4	0	0	1	
0	3 – 1 = 2	2 – 1 = 1	3 – 1 = 2	√
7 + 1 = 8	1	1	0	
√			√	

(√ indicates action to be taken in that row or that column)

Now spot the smallest element again (in Table 11.22) in the uncrossed rows or columns. It is 1. Subtract it from all elements that do not have a line through them and add it to the elements that lie at the intersection of two lines. Leave other elements untouched. Thus Table 22.23 is made.

Table 11.23

0	1 – 1 = 0	1 – 1 = 0	0
4 + 1 = 5	0	0	1 + 1 = 2
0	2 – 1 = 1	1 – 1 = 0	2
8	1 – 1 = 0	1 – 1 = 0	0

Now minimum lines required to cross all zeros of Table 11.23 are 4 = orders of the cost matrix, (you can see yourself) hence optimal solution is reached.

Since there is no row with **exactly** one unmarked zero, we start considering the columns directly. (you may consider either row or column for assignment depending on the situation).

Make assignment in cell (J_1, M_1) and delete zeros in row 1 and column 1. Make assignment in cell (J_3, M_3) and delete other zeros in column 3.

Table 11.24

	M_1	M_2	M_3	M_4
J_1	$\boxed{0}$ I	$\cancel{0}$	$\cancel{0}$	$\cancel{0}$
J_2	5	$\boxed{0}$ III	$\cancel{0}$	2
J_3	$\cancel{0}$	1	$\boxed{0}$ II	2
J_4	8	$\cancel{0}$	$\cancel{0}$	$\boxed{0}$ IV

Make assignment in (J_2, M_2) and delete other zero in column 2. Make assignment in (J_4, M_4) finally.

Optimum cost = 5 + 5 + 10 + 3 = Rs. 23

Alternate solutions are J_1M_4, J_2M_2, J_3M_1, J_4M_3 or J_1M_2, J_2M_3, J_3M_4, J_4M_1

11.6.7. Games Theory

Competition is a watchword of modern life. A competitive situation exists when two or more opposing parties are making decisions involving conflicting interests and wherein the action of one depends on the action which the opponent takes. Each opponent acts in a rational manner and tries to resolve the conflict in his own favour. Such situations arise in business, industry and in military operations, etc. Games theory is used to handle such conflicting situations. It seeks to provide a rational course of action in a conflicting situation.

Meaning of Game and Game Theory. The term 'game' represents a conflict between two or more parties. There can be several types of games, *e.g.* two person and N person games, zero-sum and non-zero sum games, constant sum game, co-operative and non-co-operative games, pure strategy games and mixed strategy games, etc.

When there are two competitors playing a game, it is called *two person game*. If the number of competitors are N (where $N > 2$), it is known as an N person game. Where the sum of amounts won by all winners is equal to the sum of the amounts lost by all losers, we call it a *zero sum game*. In a non-zero sum game or there exists a jointly preferred outcome. That is, in a zero sum game or a constant sum game the sum of gains and losses of the game is zero. As opposed to this if the sum of gains or losses is not equal to zero, we call it a *non-zero sum game*. When the best strategy for each player is to play one particular strategy throughout the game, it is known as a *pure strategy game*. In case the optimal plan for each player is to employ different strategies at different times, it is called a *mixed strategy game*. When there is communication between the participants they may reach agreement and increase their payoff through some forms of co-operation concerning the actions to be taken, so the game is called *co-operative game*, otherwise it is a non-co-operative game.

Games theory may be defined as **"a body of knowledge that deals with making decisions when two or more intelligent and rational opponents are involved under conditions of conflict and competition."** Instead of making inferences from the past behaviour of the opponent, "the approach of game theory is to seek to determine a rival's most profitable counter-strategy to one's own 'best' moves and to formulate the appropriate defensive measures". For example, if two firms are locked up in a war to maintain their market share, then a price cut by the first firm will invite reaction from the second firm in the nature of a price cut. This will, in turn, affect the sales and profits of the first firm which will again have to develop a counter-strategy to meet the challenge from the second firm. The game will thus go on. Game theory helps in determining the best course of action for a firm in view of the expected countermoves from the competitors. The competitors in the game are known as *players*. Games theory deals with competitive situations of decision-making under uncertainty.

Underlying Assumptions or Rules of Game. Games theory is applicable to situations that satisfy the following conditions :

(1) The number of competitors is finite
(2) The players act rationally and intelligently
(3) Each player has available to him a finite set of possible courses of action
(4) There is a conflict of interests between the participants
(5) The player makes individual decisions without direct communication
(6) The rules governing the choice are specified and known to the players
(7) The players simultaneously select their respective course of action
(8) The payoff (outcome) is fixed and determined in advance.

Basic Terminology. The basic elements of game theory are as follows :

1. *Payoff*. It is the outcome of playing the game or the net gain the strategy brings to the firm for any given counter-strategy of the competitor. The payoff is measured in terms of the objective of the firm like increase in profit, expansion in actual market share, etc.
2. *Payoff Matrix*. This is a table showing the outcomes or pay-off of different strategies of the game. The following table illustrates a payoff matrix of a 2 person zero sum game.

11.6.6. Assignment Problems

"The best person for the job" is an apt definition of what the assignment model seeks to accomplish. An assignment problem is a particular case of a transportation problem in which a number of operators are to be assigned to an equal number of operators where each operator performs only one operation. The objective is to maximise overall profit or minimise overall cost for a given assignment schedule.

An assignment model may be regarded as a special case of transportation model and the method for solving the assignment problems is the **Reduced Matrix Method or the Hungarian Method.** In the assignment model, the facilities represent the "sources" and the jobs represent the "destinations". Hungarian method of solution is explained in the examples ahead.

Formulation of the Assignment Model

The supply available at each centre (source) is 1 *i.e.* $a_i = 1$ for all i. The cost of transporting (assigning) facility i to job j is C_{ij}.

Step 1. The key decision is what to whom *i.e.* which sub-assembly to be assigned to which operator or what are the 'n' optimum assignments on 1-1 basis.

Step 2. Feasible alternatives are n ! possible arrangements for $n \times n$ assignment problem. The objective is to minimise the total cost involved *i.e.*

$$\text{Minimise } Z = \sum_{i=1}^{n}\sum_{j=1}^{n} C_{ij}\, x_{ij}$$

Jobs (Destinations)

Facilities (sources)	1	2	....	n
1	C_{11} (cost)	C_{12}	....	C_{1n}
2	C_{21}	C_{22}	....	C_{2n}
⋮	⋮	⋮		⋮
n	C_{n1}	C_{n2}	....	C_{nn}

Step 3. Constraints on sub-assemblies etc. are

$$x_{11} + x_{12} + x_{13} + \ldots = 1$$
$$x_{21} + x_{22} + x_{23} + \ldots = 1$$
$$\text{-------------------------------}$$
$$x_{1n1} + x_{1n2} + x_{1n3} + \ldots = 1$$

Constraints on operators or contractors etc. are

$$x_{11} + x_{21} + x_{31} + \ldots = 1$$
$$x_{12} + x_{22} + x_{32} + \ldots = 1$$
$$\text{-------------------------------}$$
$$x_{1n} + x_{2n} + x_{3n} + \ldots = 1 \qquad \text{and } x_{ij} = 0 \text{ or } 1 \text{ for all } i \text{ and } j$$

Comparing this model to TP model, we find $a_i = 1$ and $b_j = 1$ and thus assignment model is a special case of transportation model.

Example 22. HMT Ltd. decides to make four subassemblies through four contractors. Each contractor is to receive only one subassembly. The cost of each subassembly is determined by the bids submitted by each contractor and is shown in the following table in hundreds of rupees. Assign the different subassemblies to contractors to minimise the total cost.

[Calicut B.Tech 91; Patna Univ. B.E. (Mech.) 2003, 2004]

Contractors

		1	**2**	**3**	**4**
Subassemblies	**1**	15	13	14	17
	2	11	12	15	13
	3	13	12	10	11
	4	15	17	14	16

Muha...

Solution. Network formulation

$$\text{Min. } Z = (15x_{11} + 13x_{12} + 14x_{13} + 17x_{14}) + (11x_{21} + 12x_{22} + 15x_{23} + 13x_{24}) + (13x_{31} + 12x_{32} + 10x_{33} + 11x_{34}) + (15x_{41} + 17x_{42} + 14x_{43} + 16x_{44})$$

Subject to

$$x_{i1} + x_{i2} + x_{i3} + x_{i4} = 1, i = 1, 2, 3, 4$$

$$x_{1j} + x_{2j} + x_{3j} + x_{4j} = 1, j = 1, 2, 3, 4$$

and $\quad x_{ij} = 0$ or 1 for all i and j.

Step 1. Prepare a square matrix. If not make it square by adding suitable numbre of dummy rows (or columns) with zero cost elements. The step is not necessary here because we have a matrix of 4 × 4 square.

Step 2. Subtract the minimum valued element of each row from all the elements of the row. See if there is at least one zero in each row (that you will definitely get) and in each column. If you do not get at least one zero i each column then proceed to step 3.

Step 3. Now subtract the minimum valued element of each column from all the elements of the column. We see that the minimum valued elements are 13 in 1st, 11 in 2nd, 10 in 3rd and 14 in 4th row.

Now, 1st row

15	13	14	17
−13	−13	−13	−13
2	0	1	4

Simialrly complete other rows also. The result is

Table 11.17

2	0	1	4
0	1	4	2
3	2	0	1
1	3	0	2

We see that column 4 has no zero otherwise all the other columns have zeros. Now take the smallest figure *i.e.* 1 from the column and subtract it from the other elements of the column. That is

4 − 1 = 3
2 − 1 = 1
1 − 1 = 0
2 − 1 = 1

Now complete the matrix.

Step 4. Examine rows one by one and find out **Exactly** one unmarked zero. Mark this zero this like $\boxed{0}$ (*i.e.*, enrectangle or ensquare it).

It will indicate that the assignment will be made there. Mark (X) all other zeros in the **same column** showing that they cannot be used for making other assignments.

Table 11.18

2	$\boxed{0}$ I	1	3
$\boxed{0}$ II	1	$\cancel{0}$ 4	1
3	2	$\cancel{0}$	$\boxed{0}$ IV
1	3	$\boxed{0}$ III	1

Row 1 has a single unmarked zero in column 2. Make an assignment as shown $\boxed{0}$. This is sequence I. (Follow sequence I, II, III, IV for assignments).

Row 2 has a single unmarked zero in column 1, make an assignment. (Sequence II)

Row 3 has **two** zeros, so leave it for the time being. (If 3 → 3, *i.e.*, subassembly 3 is allotted to contractor 3 then zeros in row 3 and column 3 are crossed and deleted showing that they cannot be used for making other assignment. And now we cannot make assignment in row 4 and so ... the time being.

Row 4 has one unmarked zero in column 3, make an assignment and cross the other zero in column 3. (Sequence III).

Now row 3 has a **single** unmarked zero in column 4, make an assignment R_3C_4 (Sequence IV).

For an optimal solution, minimum number of lines crossing all zeros will be equal to the number of assignment to be made. Here minimum number of such lines = 4 and also the number of assignment made = 4 and hence the condition is satisfied for optimal solution.

From Table 2. It is evident that subassembly 1 to contractor 2

Subassembly 2 to contractor 1

Subassembly 3 to contractor 4

Subassembly 4 to contractor 3

$$\begin{cases} x_{12} = 1,\ x_{21} = 1,\ x_{34} = 1,\ x_{43} = 1 \\ Z\ \min = C_{12} \cdot x_{12} + C_{21} \cdot x_{21} + C_{34} \cdot x_{34} + C_{43} \cdot x_{43} \\ \quad = \text{Rs. } 4900 \end{cases}$$

$$\begin{aligned} \text{Minimum total cost } &= [(13 \times 1) + (11 \times 1) + (11 \times 1) + (14 \times 1)] \times 100] \\ &= \text{Rs. } 4900 \text{ (A unique optimal solution). } \textbf{Ans.} \end{aligned}$$

Note. You should choose the assignments very carefully in a proper sequence to solve the assignment model fully well. For example, if you follow the sequence R_3C_3(I), then R_1C_2(II) and then R_2C_1(III), then you will observe that all the assignment are **not** fully made, and row R_4 will not have any assignment.

For 3rd allocation here a tie 2 in (1, 2) and
$x_{12} = \min(6, 6) = 6$ here.

I

1	2	3	4	(6)
4	3	2	6 / 0	(8)
4 / 0	2	2	1	(10)
(4)	(6)	(8)	(6)	

II

6 / 2	3	(6)
3	2	$8 - 6 = (2)$
$\in$ / 2	2	$10 - 4 = (6)$
(6)	(8)	

III

2 / 2	(2)
6 / 2	(6)
8	
$8 - 2 = (6)$	

Now cross either the second column or the first row. 1st row is crossed.

4th allocation in (3, 2) by $\min(6 - 6, 6) = 0$ or $\in$ (epsilon) where $\in \to 0$. Put $\in$ in (3, 2) and cross second column. (This is done to remove degeneracy).

5th allocation Choose arbitrarily cell (2, 3)

Fill by $x_{ij} = \min(2, 8) = 2$

6th allocation. The choice is clear now cell (3, 3) to be filled by remaining figure 6.

Now all the rim requirements are fulfilled.

Cost $Z = (2 \times 6) + (2 \times 2) + (0 \times 6) + (0 \times 4) + (2 \times \in) + (2 \times 6) = 28 + 2\in = 28$ **Ans.**

(FINAL)

1	6 / 2	3	4	(6)
4	3	2 / 2	6 / 0	(8)
4 / 0	ε / 2	6 / 2	1	(10)
(4)	(6)	(8)	(6)	

Vogel's Approximation Method (VAM or Penality Method)—Procedural Steps

Step 1. In each row and column, calculate penalty by taking differences between minimum and next to minimum transportation cost.

Step 2. Circle the largest column difference or row difference. If both are equal, you can choose row or column with maximum allocation or the row or column having the minimum cost otherwise break the tie arbitrarily.

Step 3. Allocate as much as possible in the lowest cost cell of the row or column having a circled row or column difference.

Step 4. In case the allocation is made fully to a row or column, ignore that row or column for further consideration by crossing it.

Step 5. Revise the differences again and cross out the figure as applicable. Proceed to Step (2).

Step 6. Carry on the procedure until all rows and columns have been crossed out, *i.e.* distribution is complete.

Example 19. Use Vogel's Approximation Method to obtain an initial feasible solution of the transportation problem of example 18.

	D	*E*	*F*	*G*	**Available**
A	11	13	17	14	250 (2)
B	16	18	14	10	300 (4)
C	21	24	13	10	400 (3)
Demand	200 (5)	225 (5)	275 (1)	250 (0)	

[Bharthdasan B.Sc. Math 1993]

Solution. Differences of minimum and next to minimum are shown m brackets row-wise and column wise. The largest of these differences is (5) and associated with 1st and 2nd columns. Since the minimum cost is in (1, 1) = 11) choose column (1) we allocate x_{ij} = min (250, 200) = 200 in (1, 1) and cross the column (1). See Table 1.

Table 11.7

200 / 11	13	17	14	250
16	18	14	10	300
21	24	13	10	400
200	225	275	250	

Table 11.8

50 / 13	17	14	50(1)
18	14	10	300(4)
24	13	10	400(3)
225	275	250	
(5) ↑	(1)	(0)	

Now for **Table (2)** row and column differences are **AGAIN** computed for remaining matrix.

The largest difference is (5) in the 2nd column. In this column least cost is in C_{12} = 13 and so fill this x_{ij} by min (50, 225) = 50. Cross off 1st row.

Table 11.9

175 / 18	14	10	300(4)
24	13	10	400(3)
175	275	250	
(6) ↑	(1)	(0)	

Table 11.10

14	125 / 10	125(4)←
13	10	400(3)
275	250	
(1)	(0)	

Table 11.11

275 / 13	125 / 10	400
275	125	

For Table 11.9. Largest difference is 6 in 2nd column. In this column least cost is 18 in (2, 2). Fill this with min (300, 175) = 175. Cross off 2nd column.

For Table 11.10. Largest difference is 4 in 2nd row. In this row least cost is 10 in (2, 4) cell. Fill this with min (125, 250) = 125. Cross off 2nd row. The choice is obvious now for Table 11.11. The figure have been filled in.

Transportation Cost = Z = (11 × 200) + (13 × 50) + (18 × 175) + (10 × 125) + (13 × 275) + (10 × 125)
= 12,075 < 12200 by NWC method

Final Table

200 I / 11	50 II / 13	17	14	250
16	175 III / 18	14	125 IV / 10	300
21	24	275 V / 13	125 VI / 10	400
200	225	275	250	950

(I, II, III, ... etc. show the sequences of allotment.)

Example 20. Using Vogel's Approximation Method, solve the following transportation problem.

	D_1	D_2	D_3	D_4	Available
O_1	21	16	25	13	11 (3)
O_2	17	18	14	23	13 (3)
O_3	32	27	18	41	19 (9)
Requirement	6 (4)	10 (2)	12 (4)	15 (10)	

[Kerala B.Sc. Engg. 19

Solution.

Table 11.12

21	16	25	[11] 13	11 (3)
17	18	14	23	13 (3)
32	27	18	41	19 (9)
6 (4)	10 (2)	12 (4)	15 (10) ↑	

Table 11.13

17	18	14	[4] 23	13 (3)
32	27	18	41	19 (9)
6 (15)	10 (9)	12 (4)	4 (18) ↑	

Table 11.14

[6] 17	18	14	9 (3)
32	27	18	19(9)
6 (15) ↑	10 (9)	12 (4)	

Table 11.15

[3] 18	14	3(4)
27	18	19(9)
10 (9) ↑	12 (4)	

Table 11.16

[7] 27	[12] 18	19
7	12	

$TC = (13 \times 11) + (17 \times 6) + (18 \times 3) + (23 \times 4) + (27 \times 7) + (18 \times 12) = 796$ **Ans.**

Final Table

21	16	25	[11] I 13	11
[6] III 17	[3] IV 18	14	[4] II 23	13
32	[7] V 27	[12] VI 18	41	19
6	10	12	15	43

Note. In general VAM will give the lowest cost of bfs and is therefore, advised to the followe practice for finding initial bfs. I, II, III ... etc. show the sequence of allottments.

Example 21. Solve by VAM the following transportation problem.

	E	F	G	Supply
A	10	8	9	15
B	5	2	3	20
C	6	7	4	30
D	7	6	8	35
Demand →	25	26	49	100

Solution. NWC — Rs. 668

VAM — Rs. 538