LECTURE NOTES

ON

PLANT LAYOUT AND MATERIAL HANDLING

B.TECH VIIII SEM

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UNIT – I
PLANT LAYOUT- INTRODUCTION

INTRODUCTION

The term **Plant layout** is mainly used to represent the physical arrangement of a plant and different parts of a plant. The arrangement of machines, equipments and other industrial facilities like receiving and shipping departments, tool rooms, maintenance rooms and employee amenities which helps in attaining rapid and interrupted flow of production activities at minimum cost is usually referred to as plant layout.

The plant layout decisions mainly deals with the location on & arrangement of the production, support, customer service and other industrial facilities.

Careful layout decisions need to be made because the most important requirements of
Production process such as

- Effectiveness and efficiency of material handling,
- Utilization rates of capital equipments,
- Inventory storage levels and
- Productivity levels depend upon the layout decisions

1.1 DEFINITION OF PLANT LAYOUT:

According to 'Knowles &Thomson' Plant layout deals with

- Planning and arranging manufacturing machinery, equipment and services for the first time in completely new plants.
- The improvements in layouts already in use in order to introduce new methods and improvements in manufacturing procedure.

1.2 SCOPE OF PLANT LAYOUT:

- Plant layout has broad scope of operations as it not only deals with the primary decisions of machines and other facilities, but also concerned with all the improvements that have to be made to the existing layout based on the subsequent developments in the production methods.
- In simple terms, a plant layout is a floor plan which is meant for determining and arranging the machinery and equipment of a plant at the most suitable place such that both the materials flow and handling can be obtained at low cost.

1.3 PRINCIPLES OF PLANT LAYOUT

The following are the principles of layout which provide guidance to the layout engineer for selection of an ideal plant layout.

i. **The principle of Minimum Travel**: Operations manager must design layout in such a way that the distance between operations is minimum which intern helps in avoiding the labour & time wastages there by reducing the cost of material handling.
ii. **The Principle of Sequence:** The machines & operations must be arranged sequentially. This principle is effectively attained in product/ line layout.
iii. **The Principle of Usage:** The available space needs to be optimally utilized. This principle has wide acceptance in towns and cities where a piece of land is very much expensive
iv. **The Principle of compactness:** All the significant factors need to be fully integrated and related, producing a well integrated and final layout.
v. **The Principle of Safety & Satisfaction: The** layout must have provisions for safety of workers. It must be planned, based on the comfort and convenience of the workers for making them feel satisfied.

vi. **Principle of Flexibility:** The layout must allow improvements with less difficulty and at minimum cos.

vii. **The Principle of Minimum Investment:** The ideal layout must provide savings in fixed capital investment not by ignoring the installation of required facilities but by efficiently and optimally using the available facilities (economies of scale).

1.4 OBJECTIVES OF A GOOD LAYOUT

The main objective of a plant layout is to optimally arrange all the factors of production in such a way that it facilitates

- low production cost and
- Increased returns to scale.

For attaining this objective, the plant engineer should consider following secondary objectives while developing a plant layout.

- By minimizing and controlling the material handling & Transportation costs.
- To eliminate the hurdles and points of overloading by making use of appropriate line balancing techniques.
- To provide adequate space and to establish proper locations for both production centres and service centers.
- To minimize the waiting time of semi finished goods.
- To provide safe and adequate working conditions there by minimizing accidents.
- To ensure that the space available is utilized optimally.
- To make provisions for adequate flexibility in the designed layouts so that the minute changes in product design or changes in material specification can be accommodated easily.
- To make the plant maintenance simple & easy.
- Facilitate manufacturing process
- Facilitate organizational structure.
- Minimize investment in equipment
- To design and locate the workstations adequately to facilitate uninterrupted flow of material and movement of men.
- To encourage labour for effective utilization.
- To maintain high turnover of work in progress.
- To effectively design the layout for improving productivity and quality of product.

1.5 FACTORS INFLUENCING THE PLANT LAYOUT

The plant layout refers to the systematic arrangement of machinery, equipment and other industrial facility.

The various factors influencing the plant layout decisions are:

- **Materials:** some arrangement must be done for purpose of storing and moving the raw materials into plant until they get converted into finished products. The nature, type & form of raw material (ie liquid /solid, seasonal, market conditions,/ Material specification.
- **Product:** The nature of product (Size, demand) influences the type of layout required. Production of ship-building, the product is fixed where as the production resources such as men & machinery needs to be brought towards the product. The demand of product also affects the layout(Storage, handling)
- **Worker:** While selecting a layout, the position and requirement of employees needs to be considered. Suppose an organization only consisting of male employees then the type of layout is different from that of an organization where both men and women are employed. Such variations emerge due to differential requirements.
- The mobility of employees, also affects the plant layout.
- The other facilities such as health related, locker rooms, club, canteen ect., also affects the plant layout.
- **Machinery**: The size and type of machinery which dictated by the product type, quantity of production, management policies.
- **Type of Industry:** Plant layout decisions also influenced by the type of industry.
  - **Synthetic Industries**: In this type several elements undergo production process to form finished product.

- Ex: Chemical, paper industry

  Analytical Industries: In this type, conversion of raw material into different elements.

  ex: sugar mill produces sugar biogases, molasses, jiggery apart from sugar crystals.

  Conditioning industries: such industries produce product with variable physical properties.

  Ex: Metal working industries

  Extractive Industries: Such industries extract one element from the group of elements. ex: extraction of a metal from an ore.

VI LOCATION:

The location of the plant also affects plant layout in different way. Type of building is decided by the terrain and size of the site.

- Location: influences the plant layout decisions in following ways.
- Size & Topography decides the type of building to be constructed.
- mode of transportation:
- Fuel requirements of the firm:
- Future expansion of the firm:

  if village site is selected , the expansion of the concern may be influenced by the addition of one or more wings to the present construction. When the urban is selected, expansion is influenced by addition of several stories to the present construction. Based on no. of story, the material handling requirements can be determined which influences the plant layout.

VII MANAGERIAL POLICIES

Layout is influenced by managerial policies which are as follows.

- The production volume & scope for expansion.
- The level of automation required.
- Production or purchase of equipment.

1.6 TYPES/CLASSIFICATION OF PLANT LAYOUTS:

A plant layout mainly deals with the arrangement and grouping of machines which are used for producing goods. Mostly grouping is employed on different product lines. The selection of a particular layout relies on many factors.

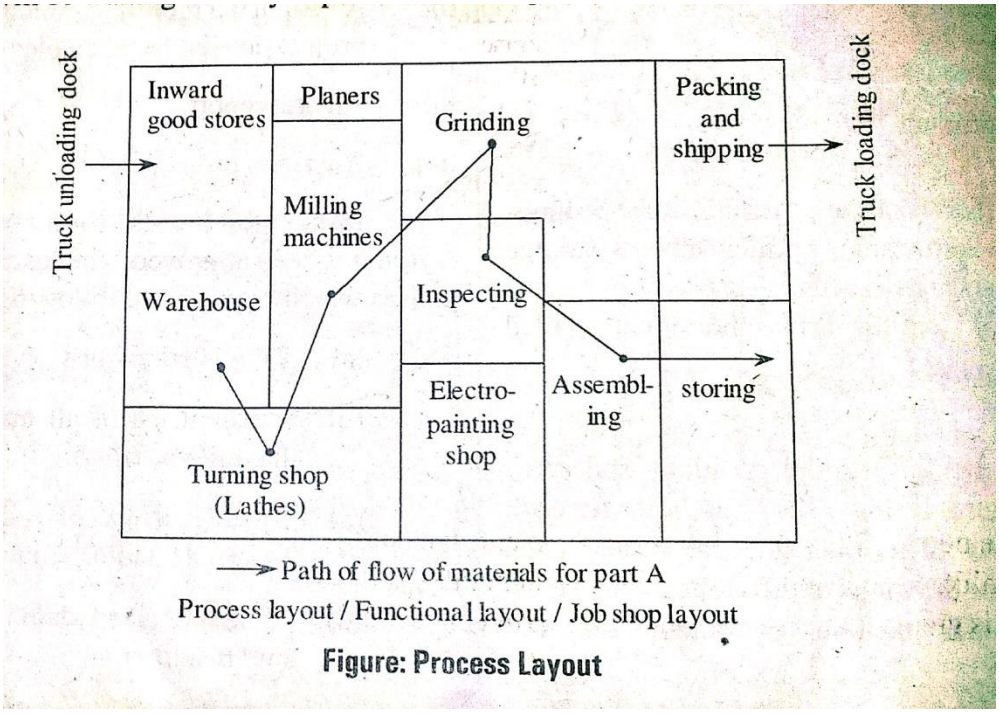
- Process layout/ Functional layout/ Job-shop layout.
- Product Layout/ Line processing layout/ flow line layout
- Fixed position Layout / Static Layout.
- Cellular manufacturing Layout/ Group Technology Layout
- Combination Layout/ Hybrid Layout.

1.6.1 PROCESS/FUNCTIONAL/JOB SHOP LAYOUT:

Process Layout: is a type of layout which is characterized by the presence of similar machines or similar operations at specified location. It is known by different names. It is also called as functional layout or Job shop layout or bath production layout.

-In Process layout: The machines are grouped on the basis of their operational characteristics. Ie machines that are performing the same operation are installed at a specific location.

-All drilling m/cs are installed in drilling dpt. All lathe machines are installed in turning dpt. All welding m/cs are installed in welding dept. This layout is very where low volume of production is required.

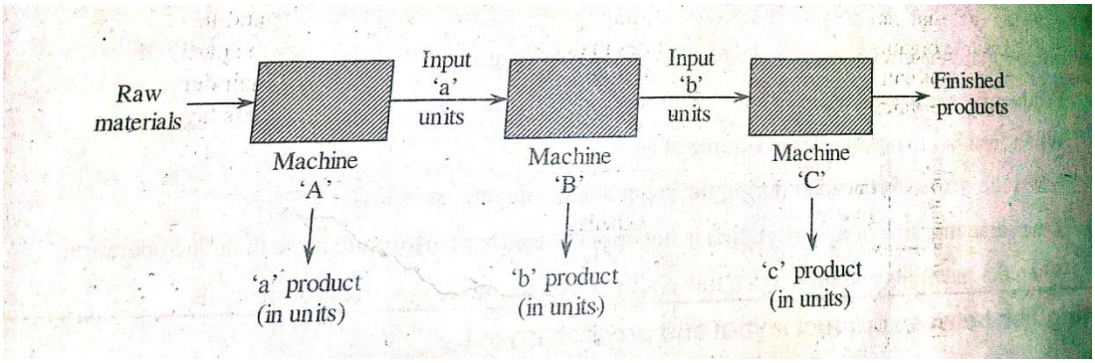


Process layout / Functional layout / Job shop layout

Figure: Process Layout

1.6.2 PRODUCT/LINE PROCESS/LINE /FLOW LINE LAYOUT:

refers to the sequential or orderly arrangement of machines in one line based on sequencing rules. It is also called as Straight line Layout or Layout for serialized manufacture in product layout machines are arranged according to process to be carried out on the product. In this layout raw materials enters from one side and leaves from other side (ie finished product). There exist several machines which are arranged as per the sequence of the operations, such that the partly processed products (WIP) of machine become an input for the other machine.



1.6.3 COMBINED LAYOUT / GROUP TECHNOLOGY LAYOUT/ HYBRID LAYOUT.

-This layout contains a mix of process and Product layout.
-This layout is considered for special production line.

A combination of product and process layouts with an emphasis on either is noticed in most industrial establishments. Plants are never laid out in either pure form. It is possible to have both types of layout in an efficiently combined form in plants involving the fabrication of parts and assembly, fabrication tends to employ the process layout while assembly areas often employ the product layout. The following figure illustrates combined layout. The departments are arranged according to type of processes, but the product flow through on a product layout.

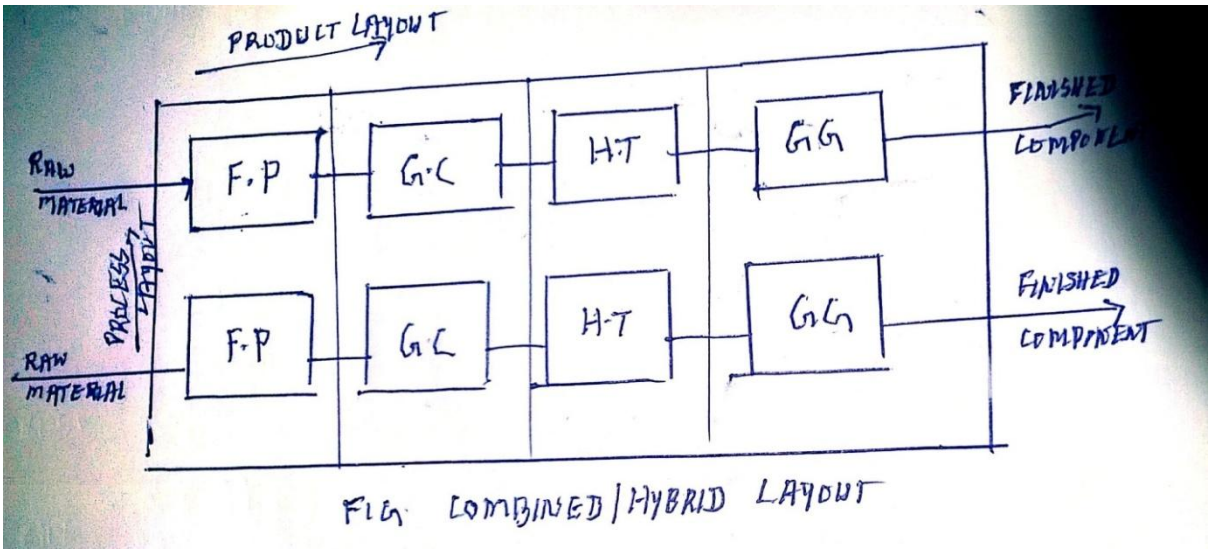


FIG COMBINED / HYBRID LAYOUT

F.P : Forging Press
H.T: Heat Treatment Furnace
GC : Gear Cutting machine
G.G: Gear Grinding machine

1.6.4 FIXED POSITION / STATIONARY LAYOUT:

In this type of layout, material remains at a fixed place and the complete job is done at a fixed station with materials.

-It involves the movement of men and machines to the product which remains stationary for the necessary operations. In this layout, major component remains in a fixed location and tools machinery and men as well as other pieces of material are brought to this location. The movement of men and machines to the product is advisable because the cost of moving them would be less than the cost of moving the product which is very bulky. This type of layout is followed in the manufacture of bulky and heavy products such as Hydraulic turbines, ship building, Locomotive Industry. Construction of building requires fixed location layout because men, cement, sand, bricks, steel, wood and others are taken to the site of construction.

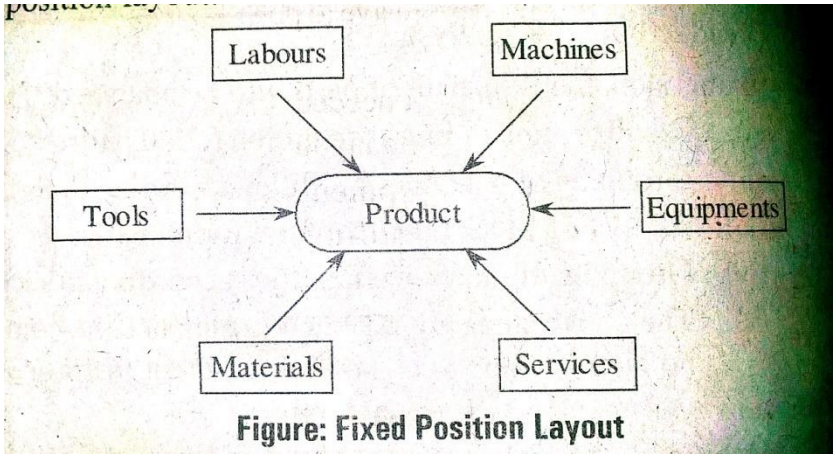


Figure: Fixed Position Layout

1.6.5 CELLULAR MANUFACTURING LAYOUT:

In this layout the machines are grouped into cells, and the cells function somewhat like a product layout with in a larger shop or process layout.

Illustration of C.M layout is shown in figure. Each cell in the CM layout is performed to produce a single parts family- a few parts, all with common characteristics which usually means that they require the same machines and have similar machine settings. The flow of parts with in cells as shown in fig can take many forms. For example, in cell #1, and cell #2, the parts in the part family flow through the same machines in a product focused, line flow fashion. But in cells #3 and #4, parts take different routes through the cells because of differences between the design of the two Parts.

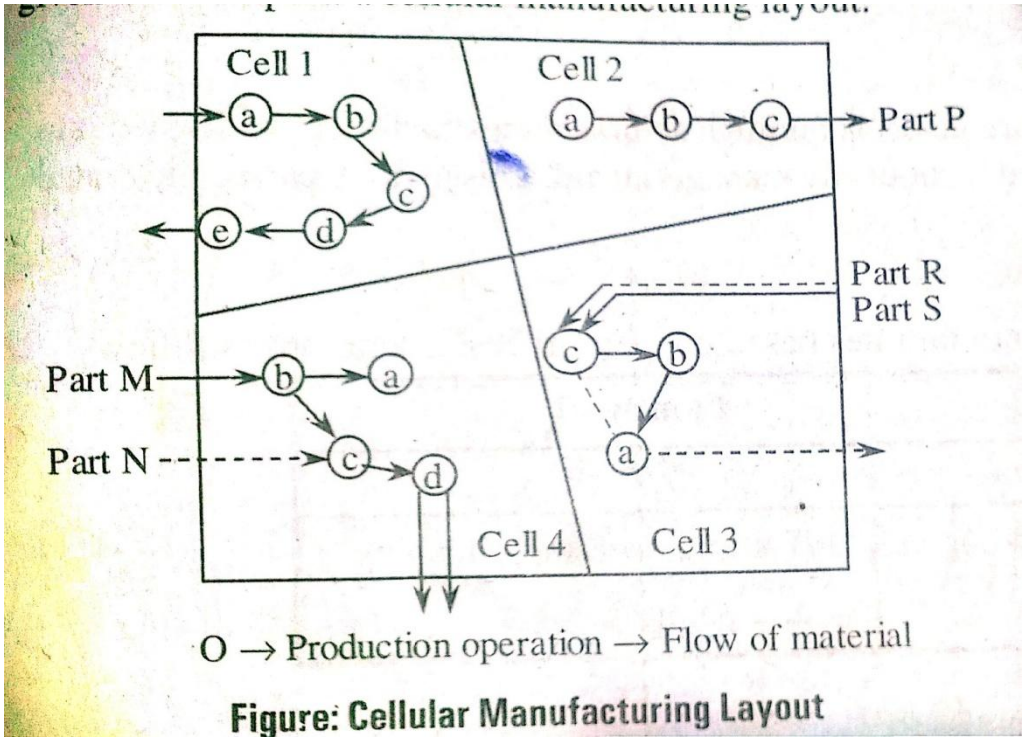


Figure: Cellular Manufacturing Layout

1.7 ADVANTAGES OF PROCESS LAYOUT

- Fewer machines are required.
- Similar job are manufactured on similar machines, hence supervision is simple.
- There will be better control on precision or complicated processes.
- Special machinery is used for performing specific job, efficient supervision can be made/achieved.
- Process layout is flexible, ie it provides greater scope for expansion as the production capabilities can be increased easily.
- A low investment on machines and equipment as general purpose machines are used.
- It helps in optimum utilization of production recourses such as men and machine equipments.
- The breakdown of the equipment can be handled in process layout by allotting the work to other machines or other work station.
- Process layout motivates the individual worker by offering increased incentives based on his performance.
- New workers have better training facilities on the job.
- Foremen become specialized in the performance of the job and know all about the equipments and their operations.

1.8 DISADVANTAGES OF PROCESS LAYOUT

- It is very much difficult to transfer the materials in process layout as mechanical devices are not able to efficiently handle the materials.
- More floor area is required for its functioning.
- Handling and back-tracking of materials is too much.
- It is very much difficult to control the various activities.
- Total production cycle time is more, due to long distances and waiting.
- Routing and Scheduling is more difficult.
- Inspection of work for each operation is necessary which causes delays.
- If more number of WIP units get accumulated near single m/c, it results in congestion problems.

1.9 ADVANTAGES OF PRODUCT LAYOUT

- The flow of product will be smooth & logical in flowing.
- Mechanical devices are used for handling materials, which helps in bringing down the cost of material handling.
- Material handling cost is minimum
- Helps in avoiding the obstructions in production.

- In-process inventory is less
- Throughput time is less
- Highly economical as it requires less time for processing.
- Operators need not be skilled.
- It motivates the group of workers by providing higher incentives to increase their performance level.
- Offers better production control., simple ppc systems are required
- It requires small floor area for producing a single unit of product.
- It reduces WIP and minimizes the investment.
- Both mistakes and the defective items can be easily detected

1.10 DISADVANTAGES OF PRODUCT LAYOUT

- Lack of flexibility in production operations
- It is not possible to supervise the operations.
- Has less scope for expansion.
- It is very expensive./ high investment is required.
- A Single breakdown of equipment along a production line can interrupt the whole system.
- A change in product design may require major alterations in the layout.
- The line output is decided by the bottleneck machine

1.11 ADVANTAGES OF FIXED POSITION LAYOUT:

- capital investment is minimum
- continuity of operation is ensured.
- Less total production cost.
- Less material movement.

1.12 DISADVANTAGES OF FIXED POSITION LAYOUT:

- machine and tools etc. take more time to reach at the work place.
- highly skilled workers are required.
- complicated jigs and fixtures may be required in fixing jobs and tools etc.

1.13 ADVANTAGES OF CELLULAR MANUFACTURING LAYOUT.

- Increases reliability of components.,
- Increases effective machine operation.
- Increases productivity.
- High costing accuracy.
- Increased customer service.
- Increased order potential.
- Reduced planning effort.
- Reduced paper work.
- Requires low setting time.
- Low machine down time.
- Low work in progress
- Low work movement.
- Reduced over all production time.
- reduced overall cost

1.15 COMPARISON BETWEEN PRODUCT LAYOUT & PROCESS LAYOUT

S.NO	Product layout	Process layout
1	Product layout involves arrangement of machines in a series based on sequence of operation	In Process layout similar machines are grouped in one dept
2	Product layout is also called as straight line layout or line layout	Process layout is also called as functional layout
3	Amount invested on purchase &	Amount invested on purchase &

	installation of machine is very high	installation of machine is very less
4	Product layout does not provide flexibility in production process	Process layout provides greater flexibility in the production process
5	no scope for expansion	Greater scope for expansion
6	Floor area required for per unit of production is less	Needs more floor space
7	As machines are arranged sequentially a single machine break down causes the whole system to disrupt.	The breakdown of m/c can be easily handled by transferr4ing work to other m/c
8	Product layout motivates a group of workers to increase their performance	Process layout motivates individual worker to increase his performance.
9	Product layout helps in better control of production process	It is very difficult to control the process of production
10	Less inspection supervision is needed	Many inspections are needed during a sequence of operations.
11	In product layout same m/c or work station will not be used for more than one operation	Same machine can be used for two or more different operation.
12	Special purpose m/c ns are used	General purpose machines are used.
13	Mechanical devices can be used easily for handling materials	Mechanical devices cannot be used easily for material handling.
14	Product layout is suitable for continu0us process industries such as car/ automobile mfg and chemical industries	Process layout is used for industries engaged in intermittent type of production.

1.16 LAYOUT PLANNING:

The engineering or planning department is responsible for designing and installing a layout.

- In the manufacturing and service organizations, the layout planning deals with the arrangement of resources so that the performance of the operating system could be improved.
- A set of tools and techniques can be provided by the layout planning which helps the operations manager to locate resources and also for assessment of alternatives for locating the resources.

The different techniques that are available and useful for layout planning are

i. Templates
ii. Operations Sequence Analysis.
iii. Line balancing.

i. **Template:** It is a two dimensional technique which is the most commonly used. Templates are the design patterns which consist of a thin plate, made up of wood or metal and which serve as a gate for performing mechanical activities.

- It constitutes the scaled representation of the physical object of the layout.
- Templates are fixed for preparing plans, for drawing several possible layouts. The best possible option can be explored by eliminating the unnecessary handling and backtracking of materials.
- It is usually employed for re-designing the existing department/building
- For verifying the layout design configuration decided by other layout technique.

II. OPERATIONS SEQUENCE ANALYSIS: It is an early approach to process type layout. It develops a good plan for arranging the departments graphically so that the layout problems get an optimal solution. Through the operations sequence analysis, the relative locations of operating department with respect to one another can be predicted.

III. LINE BALANCING: it is an important activity of an assembly line operation, which is mainly used for the equitable distribution of work among the employees so that total number of employees can be greatly reduced. Line balancing is not an easy task because there are different alternative methods that can be far more easily applied than line balancing for the decision of work. Some of the methods used by operation researchers to study line balancing problems include linear programming, dynamic programming and other optimal methods.

1.17 STEPS FOLLOWED IN DESIGNING A LAYOUT

- Statement showing the objectives, scope and factors that need to be considered
- Gather the primary data on sales forecasts, production volumes, production schedules, part lists, operations and their sequences.
- Development of flow process charts, flow diagram, string diagram, templates and so on.
- Establishment and the design of the production process.
- Material flow pattern is planned and complete material handling plan is developed.
- Computation of the requirements of work centers and equipments.
- Planning is done for individual work centers.
- Selection of proper mate9. Identifying the storage requirements
- Identifying the storage requirements
- Planning for the auxiliary and service facilities.
- Identification of routing, service department, employee facilities and requirement of
- space for each work station
- Outlining the specification of building so that the requirement s of the layout can be fixed.
- Development of floor plan for representing the location of doors, windows, stair case, lifts
- Other infrastructural facilities.
- Preparation of tentative or drafts layout plans.
- Preparation of a comprehensive layout drawing which can be even accepted by top Management
- Preparation and design of work schedules for layout installations.

1.18 CLASSIFICATION OF LAYOUT DESIGN PROCEDURES/ EVALUATING METHODS.

The design procedure s for layout is broadly classified into two type. They are,

i. Manual methods
ii. Computerized methods

i. The manual methods are conventional type and are sub-divided as follows.

a) travel chart method
b) Systematic layout planning
c) local-distance analysis method

Ii.Computerized methods are constructive type and improvement type algorithms and they are classified as follows.

a) Automated layout design program (ALDEP).
b) Computerized Relationship Layout planning (CORELAP).
c) Computerized Relative Allocation of Facilities Technique. (CRAFT)
d) Computerized Plant Layout and Evaluation Technique (PLANET).
e) Computerized Facilities Design (COFAD).

1.19 MANUAL LAYOUT DESIGN PROCEDURE:

a) **Travel chart method:** Travel chart method is a technique used for determining the overall flow of materials. The travel chart is used to identify the most active departments when materials move from one department to the other.

- In this method, the optimal solution can be reached by considering the trial and error method wherein the active departments are located centrally so as to minimize the non-adjacent flows.
- The travel chart is drawn by using circles for representing the work stations and lines for the transportation of loads across the work centers and departments.

PROCEDURE:

- Identify the departments which maintain the adjustment links with the other departments.
- in facility outline, the most active departments must be located at the central position.
- By trial and error method other departments must be located in such a way that the non-adjacent flows could be minimized to a great extent.
- By eliminating all the non-adjacent moves, the optimal solution is said to have obtained.

The travel chart is also known as home

Develop an optimum Layout with the following data by using travel chart method.

Product	% volume	sequence
1	7	S-A-B-C-D-E-F-SS
2	11	S-C-B-D-E-F-SS
3	28	S-A-B-D-C-F-SS
4	23	S-B-C-D-C-E-F-SS
5	8	S-B-C-D-E-SS

construct a chart constituting Load transactions of each cell as follow

To / From	S	A	B	C	D	E	F	SS	Total
S		35	31	11	—	—	—	—	77
A	—		35	—	—	—	—	—	35
B	—	—		38	39	—	—	—	77
C	—	—	11		38	23	28	—	100
D	—	—	—	51		26	—	—	77
E	—	—	—	—	—		41	8	49
F	—	—	—	—	—	—		69	69
SS	—	—	—	—	—	—	—		0
Total	0	35	77	100	77	49	69	77	

volumes of S to A = 7 + 28 :

S to B = 23 + 8 : 31

S to C = 11

S-D = —

S-E = —

S-F = —

volumes of A to B : 7 + 28 :

A to C : —

A to D : —

volume of B to C : 7 + 23

B to D : 11 + 28 : 3

B to E : —

B to F : —

B to SS : —

volume of C to D : 7 + 23

C to E : 23

C to F : 28

C to SS : —

volumes of D to E : 7 + 11 + 8 : 26

D to F = —

D to SS :

E to F = 23 + 7 + 11 : 41

E to SS = 8

F to SS : 7 + 11 + 28 + 23

= 69

volumes of C to B : 11

D to C = 28 + 23 : 51

Let the following areas are equal and distance between adjacent square = 1 and backtracking = 2

The distance from I diagonal =

= (35 + 35 + 38 + 38 + 26 + 41 + 69) × 1

282 × 1 = 282

The II diagonal distance = (31 + 39 + 23 + 8) × 2

= 101 × 2 = 202

III diagonal distance = (11 + 28) × 3

Back tracking I diagonal distance : 111 +

= 124

Total distance : 282 + 202 + 127 -

= 225

This required to minimize the dis by interchanging C and D to reduce back tracking.

Re draw the tabular form

II iteration is performed by interchanging C &

	S	A	B	D	C	E	F	G	Supply
S		35	31	44	11				
A			35						
B				39	38	-	-	-	
D					51	26			
C			11	38		37 (23)	28		
E							41	8	
F								69	
G									
Total	0	35	77	77	100	49	69	77	

Calculate total distance

I diagonal distance: (35 + 35 + 39 + 51 + 23 + 41 + 69) x1
= 293 x1 = 293

II diagonal distance = (31 + 38 + 26 + 28 + 38) x2
= 131 x 2 = 262

III diagonal distance: (0) x3 = 0

IV diagonal distance: = (11 + 0) x4 = 44

Back tracking 3rd diagonal distance: 38 x 2 = 76

II " " II diagonal distance: (11 + 33) 2 = 44

Total distance: = 293 + 262 + 0 + 44 + 76 + 44 = 719 kms

From the above discussion, the minimum value is obtained at II iteration as 719

∴ The II iteration represents as an optimum Layout

SYSTEMATIC LAYOUT PLANNING METHOD:

6.3.1 Systematic Layout Design Procedure

An organized approach to layout planning has been developed by Muther and has received considerable publicity due to the success derived from its application in solving a large variety of layout problems. This approach is referred to as systematic layout planning or simply SLP. This procedure is shown in Fig. 6.4. From the figure, it is clear that once the appropriate information is gathered, a flow analysis can be combined with an activity analysis to develop the relationship diagram. The space-relationship diagram is constructed by combining space considerations with the relationship diagram. Based on the space-relationship diagram, modifying considerations and practical limitations, a number of alternative layouts are designed and evaluated. In comparison with the steps in the design process, SLP begins after the problem is formulated.

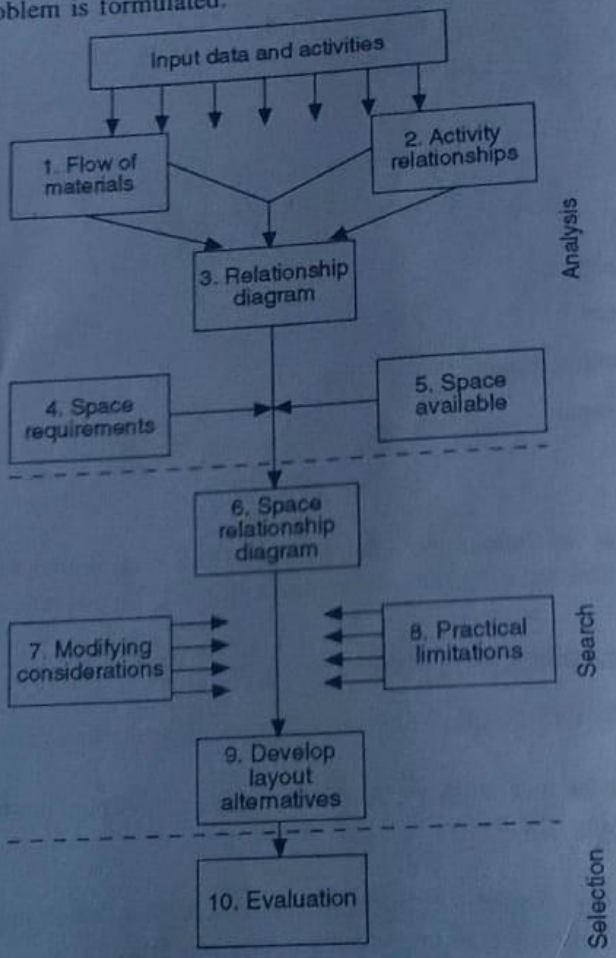


Fig. 6.4 Systematic layout planning procedure (from Francis and White, 1974).

6.3.2 Computerized Relative Allocation of Facilities Technique (CRAFT)

CRAFT algorithm was originally developed by Armour and Buffa. CRAFT is more widely used tha ALDEP and CORELAP. It is an improvement algorithm. It starts with an initial layout and improve the layout by interchanging the departments pairwise so that the transportation cost is minimize

1.20 NEED / NECESSITY FOR PLANT LOCATION:

The need for selecting a plant location emerges under any of the following conditions.

- If an entrepreneur stars a new business
- When the current business unit does not have any scope for expansion and it had outgrown its original facilities.
- When a lease expires and the landlord is not willing to extend its leasing contract.
- In case of expansion of the business volume or the degree of market.
- If a firm thinks that there is a chance of decreasing the manufacturing cost by changing from one location to other location.
- There can also be other economic or social reasons such as improper labor supply, change of market conditions etc., for selecting a plant location.

While selecting a plant location, it is very essential to consider all the economic factors influencing it. It is very difficult to select the place having all the required facilities for starting a factory. So a place providing maximum facilities must be selected.

The principle used for selecting a plant location is that place where the cost of raw material fabrication and the cost of marketing of finished product is minimum must be selected.

1.21 FACTORS TO BE CONSIDERED FOR SELECTION OF PROCESS AND PRODUCT LAYOUT

Factor	Process Layout	Product Layout
i. Products	Several types or Special order	One or few products
ii. No. of Inspectors required	More	Less
iii. Volume of Production	Relatively Low	Large
iv. No. of heavy equipment required	Maximum with some special treatments	Minimum, with very special facilities
v. Products and material handling by means of mechanical equipments	It cannot be continuous because of either heavy weight or large size	It is a continuous process
vi. Time and motion studies determines the rate of flow	Impossible	Possible
vii. Need of same work-station for different operations	Very frequently	Very rarely
viii. Balance between labour& equipment	Difficult to obtain	Easily obtained

1.22 STEP WISE PROCEDURE FOR SELECTION OF SITE (LOCATION OF SITE)

For selecting a plant location systematically, the following steps should be followed.

1. **Deciding the Domestic or International Location**: The first step involved in selecting a plant location is to take a decision for locating the facility either domestically or internationally. Traditionally, this factor was not given much importance. Due to the emergence of globalization, the issues associated with home and foreign country are gaining much more importance. If a firm selects foreign location, then the next step I would be the selection of a country which will provide all the facilities required for production process.

The selection of a particular country relies on the factors like political stability, export and import quotas, currency and exchange rates, cultural and economic features and natural or physical conditions**.**

2. **Selection of Region:**The second step involved in selection of a plant location is the selection of particular region from a group of alternative regions of a country. The factors affecting in selection of a region are as follows

1.23 PROXIMITY TO THE RAW MATERIALS:

In order to efficient locate a plant, firm need to ensure that it should near to the market place such that the production recourses (example, raw materials) can be transferred at minimum cost.

The heavy industries such as sugar industry, paper industry, iron and steel industry, and vision needs to be situated near the sources of their raw materials. The Proximity to raw material provides the following benefits to the firm.

-Decreases the transportation costs.

-Helps in smooth supply of raw materials without any interruptions by transportation break downs.

- Saves the storage cost of materials.

1.24 PROXIMITY TO THE MARKET:

As the goods are mainly produced for selling them to customers, firms need to locate the plants close to their market, so that the customers may be served promptly if they have quick access to the markets. This helps in improving satisfaction levels of customer. The benefits of having proximity to market are Helps in reducing he transportation cost while transferring the finished goods to the market. Helps in implementing replacement orders without delay.

- Improving customer satisfaction as it helps in providing prompt service to the customers. Helps the firm to alter their production program as per the likes and dislikes of the consumers. Provides after sales service to the customers

1.25AVAILABILITY OF POWER:

Power plays a very important role in an

Industry. Coal, electricity, oil and natural gas are the important power sources. The iron and steel industry in which the coal acts as a power source, needs to be situated near the coal fields. Some of the examples such type of industry are iron and steel industry in Jamshedpur. The firms must locate their plants near to the place where electric power is regularly available at least cost. In modern industries, electricity is regarded as an important source of power as it helps in cleaning, handling and manufacturing.

2.4 TRANSPORT FACILITIES:

The transportation facility is one of the most important factors affecting the plant location. It is the transportation facility which helps in transferring the raw materials and men to the factory and also for transferring the finished products from factory to the market.

2.5 CLIMATE SUITABILITY:

Climatic influences the plant location in two ways .some industries need particular climatic conditions due to nature of their production example humid climate is required for cotton textiles and jute. Climate influences the efficiency of labour. Severe climatic conditions influences labour efficiency and does not attract the industries.

2.6 GOVERNMENT POLICY: The firms which want subsidies or incentives must locate their factories in the states which provide them. Indian government holds an impact on the plant location in the following manner. 1. Licensing policy 2. Freight rate policy 3. Institutional finance and government subsidies 4. Developing a public sector unit in an isolated area and attracting the other industries.

2.5 **Competition among the states:** states compete with each other for attracting new industries. Many states provide investment subsidies and exemptions for establishment of new industries. These incentives are not much importance to large size firms. But these incentives are very important for small and medium sized firms.

3. SELECTION OF COMMUNITY/LOCALITY:

3.1AVAILABILITY OF LABOUR:

Labour plays a very important role in the industries which produce goods or services. The success of organization depends on the timely availability of labour at reduced wages. However, skilled labours have an impact on the plant location decisions rather than an unskilled labour as they will be immensely available globally. Attitude of workers, union activities & industrial disputes which discourages the existing factories to establish their new work centers in such locations.

3.2 CIVIC AMENITIES FOR WORKERS:

Workers also require external facilities in addition to good working conditions with in the factory such as

3.3 EXISTENCE OF COMPLEMENTARY AND COMPETING INDUSTRIES:

The existences of complementary industries are also considered while locating a plant which provides .benefits. if same industries are situated at one place then it helps in improving the proximity of labour.

3.4 FINANCE AND RESEARCH FACILITIES:

it is very much important to have sufficient capital. New industries are attracted towards the place where there in a financial opportunities to expand their scope of operation.

3.5 AVAILABILITY OF WATER &FIRE FIGHTING FACILITIES:

3.5 LOCAL TAXES AND RESTRICTIONS

3.6 PERSONAL FACTORS

4 SELECTION OF A SITE:

The selection of a site involved in plant location is the selection of an appropriate site in a Selected locality. Factors affecting the solution of site are

4.1 SOIL, SIZE AND TOPOLOGY:

Soil, or its fertility does not affect the v plant location of the factories which manufacture engineering goods. But for the establishment of agro based industries, fertile soil plays a very important role as entire production is based on the fertility and nature of soil of a site. The piece of land selected must provide both the existing manufacturing facilities as well as the facilities for future scope for expansion. Topography of place must also be considered as non-uniform land may not serve the purpose and requires leveling which is a costlier affair.

4.2 WASTE DISPOSAL:

The industries such as chemical, sugar, steel, leather and breweries commonly face the problem of disposal of waste or effluents. There should be provision for sufficient land so as to dispose the solid waste, liquid waste.

4.3 GOOD SCENERY:

The site selected for plant location must be away from the residing areas or must be located in remote areas, so that the effluents emitted from such industries may not affect the health of the population.

1.23 EVALUATION, SPECIFICATION AND INSTALLATION OF A LAYOUT:

EVALUATION OF LAYOUT:

Evaluation of layout can be carried out for an existing layout or an alternate layout. The principle features of evaluation of layout are as follows.

I. The primary objectives of plant layout planning.
II. Evaluation of productivity, space, ranking etc.
III. Comparison of costs with other alternative layouts.
IV. Evaluation of elusive factors based on judgment,
V. Pilot plant evaluation.
VI. Evaluation of sequencing of operations on several work stations.
VII. Evaluation of various factors based upon their significance.

1.24 SPECIFICATIONS OF LAYOUT:

Specifications of plant layout according to the type of plan are as follows.

i. Plot plan
ii. Block plan
iii. Detailed drawing.

PLOT PLAN:

Plot plan consists of outline structure, surroundings, location, total area covered, major entities Such as storage tanks, dumping yard, parking slots, etc. This plan represents as the master

drawing for locating various individual detailed drawings.

BLOCK PLAN:

Block plan consists of internal positions and areas allotted to each department. It shows the boundaries for each and every divisional area. This plan is represented as reference plan for detailed drawings of different departments. This plan does not include machines, equipment and other utilities.

DETAILED DRAWING:

Detailed drawing consists of an individual machinery, material handling equipment, position of operators, temporary work in process storage, etc. it also includes the arrangement of supporting activities. This drawing represents the flow of work process in an individual department. The construction of detailed drawing can be carried in three different methods.

i)Templates ii)Drafting iii) Models

i. **Templates:** templates are the design pattern consisting of thin plate, made of wood or metal sheets. It serves as a gateway forb performing mechanical activities. It constitutes the scaled representation of physical objects of the layout.
ii. **Drafting**: drafting involves sketching of work process flow along with the machinery and equipment in 2D and 3D, it can be obtained by either manual drafting or by using CAD software.
iii. **Models:** The models are three dimensional representation of objects which are made by cardboard, plastic, paper or sheet metal. It gives a replica layout and also makes the model in an attractive presentation.

1.25 INSTALLATION OF LAYOUT:

The installation of a layout commences only when following reports fulfill the requirements.

- A visualized representation of layout which includes project details, facts, display charts , etc.
  An oral report
- A written project report
  Installation process for a layout starts after the final layout has been approved. The installation Starts in different phases which require the following documents.
- Detailed drawings.
- Detailed list of all machines, equipments and facilities required.
- Specification of individual production and material handling equipment.
- Scheduling and planning reports of construction and installation.

UNIT – II

2.0. HEURISTICS FOR PLANT LAYOUT:

When there is no method which guarantees an optimal solution with reduced computational effort, in such situation we aim at a solution which is not necessarily optimal but which is near optimal. The method to get such a solution is known as heuristic method. Here an attempt is made to strike a compromise between the computational effort and the quality of the solution.

The numbers of heuristics to solve the layout problems are as follows.

- Computerized Relative Allocation of Facilities technique (CRAFT)
- Automated design layout design program (ALDEP)
- Computerized Relationship Layout Planning (CORELAP)
- Computerized Facilities and Design (COFAD)
- Plant Layout Evaluation Technique (PLANET)

2.1 NEED FOR USING COMPUTER PROGRAMS:

Generally, plant layout problems are conjunctional problems which take more time for evaluating the best design layout by using many interchangeable departments with different locations using analytical methods. In order to reduce time consumption, computer programs are used, which performs as many evaluations of interchangeable departments with locations in a very short period of time. Thus the need of software programs in plant layout is very advantageous.

2.2 CLASSIFICATION OF COMPUTER PROGRAMS OF PLANT LAYOUT:

The computer programs can be classified based on two perceptions.

- Construction of Algorithms: Computer programs help in constructing the algorithms. A construction algorithm includes the proper selection and placement of activities (departments), thus helps in obtaining successive design layout.

- Improvement of Algorithms: This perception of computer program provides an idea about improvement in the quality of layout problem. In order to improve the quality design layout, the activities (departments) are interchanged from the initial existing layout.

The following computer programs are most commonly used in designing a plant layout.

- Computerized Relative Allocation of Facilities Technique (CRAFT)
- Automated design layout design program (ALDEP)
- Computerized Relationship Layout Planning (CORELAP)
- Computerized Facilities and Design (COFAD)
- Plant Layout Evaluation Technique (PLANET)

Model ii, iii are construction algorithm which generate layout by successive addition of facilities to locations. Model is an improvement algorithm which takes, an input and improves to optimal solution in a number of iterations.

2.3 COMPUTERIZED RELATIVE ALLOCATION OF FACILITIES ECHNIQUE (CRAFT) :

Computerized relative Allocation of Facility Technique (CRAFT) is the first improvement algorithm which is most widely used in plant layout design. This algorithm minimizes the material handling cost between the departments. CRAFT not only help[s in designing layout by considering material handling cost, but also provide advancement in designing layout by considering the interpretation not material flow. Initially CRAFT performs the evaluation of given layout, hence considers the effects on design layout by interchanging the departments. A pair wise exchange criteria gives an optimum results, to minimize the transportation cost between the departments. The interchanging of the departments continues to extreme limit, where no further improvements can be made. In this locations are exchanged w.r.t similar are or with common border. It allows some departments to be fixed in position so that there is no chance of exchanging the locations.

2.4 INPUT REQUIREMENTS OF CRAFT: CRAFT requires input requirement in terms of

- Total number of Departments
- Number of interchangeable departments
- Number of fixed departments with their location.
- Location of those departments.

- Area of each department.
- Initial Layout
- Flow data (matrix which shows no of unit loads moving between all depts
- Cost per unit distance (cost matrix)

2.4 **STEPS INVOLVED IN CRAFT:** The steps involved in CRAFT are as follows.

Step-1: Provide input requirement in terms of

- Total number of Departments
- Number of interchangeable departments
- Number of fixed departments with their location.
- Location of those departments.
- Area of each department.
- Initial Layout
- Flow data (matrix which shows no of unit loads moving between all departments.
- Cost per unit distance (cost matrix)

Step-2: compute centroids of all the departments in the present layout.

Step-3: Form the distance matrix by using centroids**.**

Step-4:. Given data on flow, distance and cost, compute the total handling cost of the present layout.

Step-4.: Find all the possible pair wise interchanges of departments based on concept of common border or equal area.

Step-5: for each possibility, interchange the corresponding centroids and compute approximate costs.

Step-6: Find the pair of departments corresponding to minimum handling cost from among all the possible pair of interchanges.

Step-7: Is the cost in the previous is less than the total cost of the present layout? If yes, go to step-8. If not go to step-11.

Step-8: Inter change the selected pair of departments. Call this as the NEW-LAYOUT. Compute centroids, distance matrix and total cost**.**

Step-9: is the cost of new layout is less than the cost of the present layout?

If yes go to step-10. If not go to step-11.

Step-10: The new layout is here after considered as the present layout. The data on centroids, layout matrix and the total cost is retained. Go to step-5.

Step-11: Print the present layout as the FINAL LAYOUT.

Step-12: stop the process.

2.6 ADVANTAGES OF CRAFT: Advantages of CRAFT algorithm program are as follows:

- Possibility of changing the input shapes
- CRAFT allows fixing of special locations.
- Computation speed of RAFT is fast and economical in operations.
- It can perform Mathematical operations easily.
- It is possible o check earlier interactions to run the program.
- It can be used for office layouts.

2.7 DISADVANTAGES/ LIMITATIONS OF CRAFT:

- Due to the need of initial layout, the program is strictly applied only to modify the already existing layout or to plan the new layout where borders (outline) are known.
- Distance between the departments is represented as a straight line.
- It requires manual adjustments.
- It does not provide the assurance of having lowest possible cost layout.
- It is difficult to improve the program produced by heuristic and sub-optimal procedure (CRAFT)
- While feeding the input data in a program, it requires an attentive construction.
- It requires better adaptation for resettlements.

- The solution obtained from CRAFT program mainly depends on the path
- It considers the unpleasant relationships.
- CRAFT is restricted to 40 departments.

2.8 PROBLEM ON CRAFT:

Evaluate an optimum layout by using CRAFT algorithm for the following data

|<-4->| 2 |<-4->|

4

4

1	5	4
2	3	

Initial layout

Department	1	2	3	4	5
Area (sq. units)	16	16	24	16	8

Area of departments

F^t	1	2	3	4	5
1	-	1	1	1	1
2	1	-	1	1	1
3	1	1	-	1	1
4	1	1	1	-	1
5	1	1	1	1	-

Cost matrix

F^t	1	2	3	4	5
1	-	5	2	4	0
2	0	-	2	5	0
3	2	0	-	0	5
4	3	0	1	-	0
5	0	0	2	0	-

flow matrix

Solution to CRAFT problem

Stepp-1: note the input to CRAFT program application
Number of departments = 5
Total number of interchangeable departments = 5
Initial layout,
cost matrix, flow matrix ,
Area of individual departments
.

F^t	1	2	3	4	5
1	-	1	1	1	1
2	1	-	1	1	1
3	1	1	-	1	1
4	1	1	1	-	1
5	1	1	1	1	-

Cost matrix

|<-4->| 2 |<-4->|

4

4

1	5	4
2	3	

cost matrix

Initial layout

department	1	2	3	4	5
Area (sq. units)	16	16	24	16	8

Area of departments

F^t	1	2	3	4	5
1	-	5	2	4	0
2	0	-	2	5	0
3	2	0	-	0	5
4	3	0	1	-	0
5	0	0	2	0	-

Flow matrix

STEP-2: EVALUATING CENTROIDS FOR ALL DEPARTMENTS.

Centroid for dept-1 = (x_1, y_1) = *(4/2 , 4+ 4/2)* = *(2, 6)*
Centroid for dept-2 = (x_2, y_2) = *(4/2 , 4/2)* = *(2, 2)*
Centroid for dept-3 = (x_3, y_3) = *(4+ 6/2 , 4/2)* = *(7, 2)*
Centroid for dept-4 = (x_4, y_{14}) = *(6+ 4/2 , 4+ 4/2)* = *(8, 6)*
Centroid for dept-5 = (x_5, y_5) = *(4+2/2 , 4+ 4/2)* = *(5, 6)*

STEP-3: USING CENTROIDS, FORM THE DISTANCE MATRIX.

The distance between two departments $d_{ij} = |x_i - x_j| + |y_i - y_j|$ where $x_{i,\ldots}X_j$and $y_i, \ldots y_j$ are the centrods od department i & j respectively.
Distance from dept-1 to dept-2 = $d_{12} = |x_2 - x_1| + |y_2 - y_1| = |2-2| + |2-6| = 4$
Distance from dept-1 to dept-3= d13 = $|x3 - x1| + |y3 - y1| = |7-2| + |5+4| = 9$
Distance from dept-1 to dept-4= d14 = $|x4 - x1| + |y4 - y1| = |8 - 2| + |6 - 6| = 6$
Distance from dept-1 to dept-5= d15 = $|x5 - x1| + |y5 - y1| = |5 - 2| + |6 - 6| = 3$
Distance from dept-2 to dept-3= d23 = $|x3 - x2| + |y3 - y2| = |7-2| + |2 - 2| = 5$
Distance from dept-2 to dept-4 = d24 = $|x4 - x2| + |y4 - y2| = |8 - 2| + |6 - 2| = 10$
Distance from dept-2 to dept-5= d25 = $|x5 - x2| + |y5 - y2| = |5 - 2| + |2 - 6| = 7$
Distance from dept-3 to dept-4 = d34 = $|x4 - x3| + |y4 - y3| = |8 - 7| + |6 - 2| = 5$
Distance from dept-3 to dept-5 = d35 = $|x5 - x3| + |y5 - y3| = |5 - 7| + |6 - 2| = 6$
Distance from dept-4 to dept-5= d45 = $|x5 - x4| + |y5 - y4| = |5 - 8| + |6 - 6| = 3$
Form the distance matrix as shown below.

Distance matrix

F^t	1	2	3	4	5
1	-	4	9	6	3
2	4	-	5	10	7
3	9	5	-	5	6
4	6	10	5	-	3
5	3	7	6	3	-

STEP-4 : EVALUATING THE TOTAL HANDLING COST FOR THE PRESENT LAYOUT

Total handling cost = $T_{hij} = = \sum_{i,j=1}^{5} f_{ij} * d_{ij} * c_{ij}$

$T_{h12} = f_{12} * d_{i12} * c_{12} = 5 * 4 * 1 = 20$
$T_{h13} = f_{13} * d_{i13} * c_{13} = 2 * 9 * 1 = 18$
Similarly for all consecutive departments , the total cost is evaluated and formulated as below.

Total cost matrix = flow matrix * distance matrix * cost matrix.

F^t	1	2	3	4	5
1	-	5	2	4	0
2	0	-	2	5	0
3	2	0	-	0	5
4	3	0	1	-	0
5	0	0	2	0	-

Flow ma

F^t	1	2	3	4	5
1	-	4	9	6	3
2	4	-	5	10	7
3	9	5	-	5	6
4	6	10	5	-	3
5	3	7	6	3	-

distance matrix

F^t	1	2	3	4	5
1	-	1	1	1	1
2	1	-	1	1	1
3	1	1	-	1	1
4	1	1	1	-	1
5	1	1	1	1	-

cost matrix

F^t	1	2	3	4	5
1	-	20	18	24	0
2	0	-	10	50	0
3	18	0	-	0	30
4	18	0	5	-	0
5	0	0	12	0	-

total cost matrix

Total cost = 20 + 18 + 24+ 10 + 50 +18 +30 + 18 + 5 +12 = 205

STEP-5 + CHECKING FOR THE INTERCHANGEABLE DEPARTMENTS IN THE PRESENT LAYOUT FOR IMPROVEMENT.

It can perform Mathematical operations Inter changing criteria is based on two parameters

- Departments with common border
- Department having equal area
- For present layout, eight kinds of interchanges are possible as shown below.

S No	Department Pairs	Interchanging criteria	Total cost
1	1 and 2	Common border	
2	1 and 3	Not possible	
3	1 and 4	Equal area	
4	1 and 5	Common border	
5	2 and 3	Common border	
6	2 and 4	Equal area	
7	2 and 5	Not possible	
8	3 and 4	Common border	
9	3 and 5	Common border	
10	4 and 5	Common border	

|<-4->| 2 |<-4->|

___
4
____
4
___

Initial

1	5	4
2	3	

layout

Alternate -1 : for interchange of dept-1 and dept-2, the centroids will change as below

|<-4->| 2 |<-4->|

___ (x1,
4 (x2,
(x3, y3) = (
---- (x4,
4
____

2	5	4
1	3	

Y1) = (4/2, 4/2 0 = (2, 2)
y2) = (4/2, 4+4/2) = (2,6)
4+ 6/2, 4/2) = (7, 2)
y4) = (6 +4/2 , 4 + 4/2) = (8, 6)
(x5, y5) = (4 +2/2, 4+ 4/2) = (5, 6)
d_{12}= |2 – 2| + |2-6 | = 4 d23 = |2-7| + |6-2| = 9
d13 = | 2 – 7 | + |2 – 2| = 5 d24 = | 2- 8 | + | 6 – 6| =6

. d14 = |2 – 8| = | 2 – 6 | = 10 d25 = | 2 – 5 | + |6 – 6) = 3
. d15 = |2 – 5 | + | 2 – 6| = 7 d34 = | 7 – 8 | = | 2 – 6 | = 5
D45 = | 8 – 5| + | 6 – 6| =3 d35 + | 7 – 5 | + | 2 – 6| = 6

Total cost matrix = flow matrix * distance matrix * cost matrix

F^t	1	2	3	4	5
1	-	5	2	4	0
2	0	-	2	5	0
3	2	0	-	0	5
4	3	0	1	-	0
5	0	0	2	0	-

Flow matrix

F^t	1	2	3	4	5
1	-	1	1	1	1
2	1	-	1	1	1
3	1	1	-	1	1
4	1	1	1	-	1
5	1	1	1	1	-

cost matrix

F^t	1	2	3	4	5
1	-	20	10	40	0
2	0	-	18	30	0
3	10	0	-	0	30
4	30	0	5	-	0
5	0	0	12	0	-

total cost matrix

Total cost = 20 + 10 +40+ 18 + 30 +10 +30 + 30 + 5 +12 = 205

Alternate-2: For interchanging ept-1 and department-4 centroids will change as below

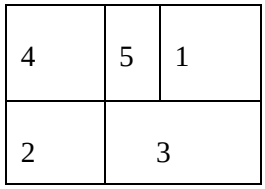
|<-4->| 2 |<-4->|

4

4

x1,y1 = (8, 6)

x2, y2 = (2, 2)
x3,y3 = (7, 2)
x4, y4 = (2, 0)
x5, y5 = (5, 6)



Alt-2 layout

Total cost matrix = flow matrix * distance matrix * cost matrix

F^t	1	2	3	4	5
1	-	5	2	4	0
2	0	-	2	5	0
3	2	0	-	0	5
4	3	0	1	-	0
5	0	0	2	0	-

Flow matrix

F^t	1	2	3	4	5
1	-	10	5	6	3
2	10	-	5	4	7
3	5	5	-	9	6
4	6	4	9	-	3
5	3	7	6	3	-

distance matrix

F^t	1	2	3	4	5
1	-	1	1	1	1
2	1	-	1	1	1
3	1	1	-	1	1
4	1	1	1	-	1
5	1	1	1	1	-

cost matrix

F^t	1	2	3	4	5
1	-	50	10	24	0
2	0	-	10	20	0
3	10	0	-	0	30
4	18	0	9	-	0
5	0	0	12	0	-

total cost matrix

Total cost = 50+ 10 +24+ 10 + 20 +10 +30 + 18 + 9+12 = 193

Alternate-3: For interchanging dept-1 and department-5 centroids will change as below

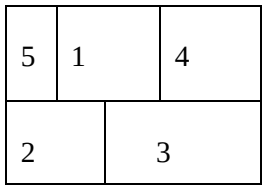
|<-2 |< 4---|<-4->|

4

4

x1,y1 = (4, 6)

x2, y2 = (2, 2)
x3,y3 = (7, 2)
x4, y4 = (8,6)
x5, y5 = (1, 6)



Alt-3 layout

Total cost matrix = flow matrix * distance matrix * cost matrix

F^t	1	2	3	4	5
1	-	5	2	4	0
2	0	-	2	5	0
3	2	0	-	0	5
4	3	0	1	-	0
5	0	0	2	0	-

Flow matrix

F^t	1	2	3	4	5
1	-	6	7	4	3
2	6	-	5	10	5
3	7	5	-	5	10
4	4	10	5	-	7
5	3	7	10	7	-

distance matrix

F^t	1	2	3	4	5
1	-	1	1	1	1
2	1	-	1	1	1
3	1	1	-	1	1
4	1	1	1	-	1
5	1	1	1	1	-

cost matrix

F^t	1	2	3	4	5
1	-	30	14	16	0
2	0	-	10	50	0
3	14	0	-	0	50
4	12	0	5	-	0
5	0	0	20	0	-

total cost matrix

Total cost = 30+ 14+16+ 10 + 50 +14 +50 + 12 + 5+20 = 221

Alternate-4: For interchanging dept-2 and department-3 centroids will change as below

| <-4- | 2|<-4->|

4

4

Alt-4

1	5	4
3		2

x1,y1 = (2, 6)
x2, y2 = (8, 2)
x3,y3 = (3, 2)
x4, y4 = (8,6)
x5, y5 = (5, 6)

layout

. d12= |*2 –* *8| = | 6-8 | = 10* *d23 = | 8 – 3 | + |2–2) = 5*
d13 = |2 – 3| = | 6-2 | = 7 *d24= | 8 – 8| + |2 – 6) = 4*
. *d14= |2 – 8 | + | 6 – 6| = 6* *d25 = | 8 – 5 | = | 2 – 6 | = 7*
. *d15 = | 2 – 5| + | 6 – 6| =3* *d34 = | 3 –8 | + | 2 – 6| = 9*
. *D35 = | 3 – 5| + | 2 – 6| = 6* *d45 = | 8-5 | + | 6 – 6| = 3*

Total cost matrix = flow matrix * distance matrix * cost matrix

F\t	1	2	3	4	5
1	-	5	2	4	0
2	0	-	2	5	0
3	2	0	-	0	5
4	3	0	1	-	0
5	0	0	2	0	-

F\t	1	2	3	4	5
1	-	10	7	6	3
2	10	-	5	4	7
3	7	5	-	9	6
4	6	4	9	-	3
5	3	7	6	3	-

F\t	1	2	3	4	5
1	-	1	1	1	1
2	1	-	1	1	1
3	1	1	-	1	1
4	1	1	1	-	1
5	1	1	1	1	-

F\t	1	2	3	4	5
1	-	50	14	24	0
2	0	-	10	20	0
3	14	0	-	0	30
4	18	0	9	-	0
5	0	0	14	0	-

Flow matrix distance matrix cost matrix total cost matrix
Total cost = 50+ 14+24+ 10 + 20 +14 +30 + 18 + 9+ 14 = 203

Alternate-5: For interchanging dept-2 and department-4 centroids will change as below

| <-4- | 2|<-4->|

4

4

Alt-4

1	5	2
4	3	

x1,y1 = (2, 6)
x2, y2 = (8, 6)
x3,y3 = (7, 2)
x4, y4 = (2,2)
x5, y5 = (5, 6)

layout

. d12= |*2 –* *8| = | 6-6 | = 6* *d23 = | 8 – 7 | + |6 –2) = 5*
d13 = |2 – 7| = | 6-2 | = 9 *d24= | 8 – 2| + |6– 2) = 10*
. *d14= |2 – 2 | + | 6 – 2| = 4* *d25 = | 8 – 5 | = | 6 – 6 | = 3*
. *d15 = | 2 – 5| + | 6 – 6| =3* *d34 = | 7 –2 | + | 2 – 2| = 5*
. *D35 = | 7 – 5| + | 2 – 6| = 6* *d45 = | 2 - 5 | + | 2 – 6| = 7*

Total cost matrix = flow matrix * distance matrix * cost matrix

F\t	1	2	3	4	5
1	-	5	2	4	0
2	0	-	2	5	0
3	2	0	-	0	5
4	3	0	1	-	0
5	0	0	2	0	-

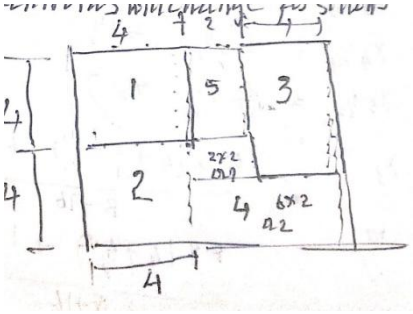
F\t	1	2	3	4	5
1	-	6	9	4	3
2	6	-	5	10	3
3	9	5	-	5	6
4	4	10	5	-	7
5	3	3	6	7	-

F\t	1	2	3	4	5
1	-	1	1	1	1
2	1	-	1	1	1
3	1	1	-	1	1
4	1	1	1	-	1
5	1	1	1	1	-

F\t	1	2	3	4	5
1	-	30	18	16	0
2	0	-	10	50	0
3	18	0	-	0	30
4	12	0	5	-	0
5	0	0	12	0	-

Flow matrix distance matrix cost matrix total cost matrix
Total cost = 30+ 18+16+10 + 50 +18+30 + 12 + 5+ 12 = 201

Alternate-6: For interchanging dept-3 and department-4 centroids will change as follows



x1,y1 = (2, 6) , **x2, y2 = (2,2)**

x3,y3 = (8, 5) **a1 = 2*2 = 4**

x5, y5 = (5 ,6) ***a2= 6*2=12***

x4, y4 = { ($a_1 x_1 + a_2x_2$)/ (a_1+a_2), ($a_1 y_1 + a_2y_2$)/ (a_1+a_2)

= { (4 * 5) + 12 * 7)/(4+12) , (4*3 + 12 *1)/ (4+12)= 6.5, 1.5)

Alt-6 layout

d12= |2 – 2| = | 6-6 | = 6 ***d23 = | 2 - 8 | + |2 – 5) = 9***

d13 = |2 – 8| = | 6-5 | = 7 ***d24= | 2 – 6.5 | + | 2 – 1.5) = 5***

d14= |2 – 6.5 | + | 6 – 1.5 | = 9 ***d25 = | 2 – 5 | = | 2 – 6 | = 7***

d15 = | 2 – 5| + | 6 – 6| =3 ***d34 = |8 – 6.5 | + |5 – 1.5 | = 5***

d35 = | 8 – 5| + | 5 – 6| = 4 ***d45 = | 6.5 - 5 | + | 1.5 – 6| = 6***

Total cost matrix = flow matrix * distance matrix * cost matrix

F\t	1	2	3	4	5
1	-	5	2	4	0
2	0	-	2	5	0
3	2	0	-	0	5
4	3	0	1	-	0
5	0	0	2	0	-

F\t	1	2	3	4	5
1	-	4	7	9	3
2	4	-	9	5	7
3	7	9	-	5	4
4	9	5	5	-	6
5	3	7	4	6	-

F\t	1	2	3	4	5
1	-	1	1	1	1
2	1	-	1	1	1
3	1	1	-	1	1
4	1	1	1	-	1
5	1	1	1	1	-

F\t	1	2	3	4	5
1	-	20	14	36	0
2	0	-	18	25	0
3	6	0	-	0	20
4	12	0	5	-	0
5	0	0	14	0	-

Flow matrix distance matrix cost matrix total cost matrix

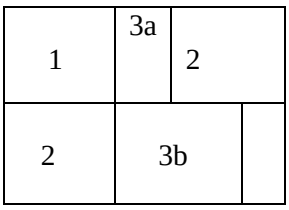
Total cost = 20+ 14+36+18 +25 + 6 + 20 + 12 + 5 + 14 = 170

Alternate-7 : For interchanging dept-2 and department-4 centroids will change as below

| <-4- | 2 |<-4->|

4

4



x1,y1 = (2, 6)

x2, y2 = (2, 2)

x4, y4 = (8, 6)

x5, y5 = (9,2)

x5, y5 = (5, 6)

x3, y3 = { (3a. $3a_x$ + 3b . $3b_x$) / (3_a+ 3_b), (3a . 3ay+ 3b . $_{3by}$)/ (3_a+ 3_b) }

*$x_{3,}$ y_3 = { (8 * 3 + 16 * 5)/ (8+16), (8 * 5 + 16*2) / (8+16) = (6, 3.33)*

*= { (4 * 5) + 12 * 7)/(4+12) , (4*3 + 12 *1)/ (4+12)= 6.5, 1.5)*

. d12= *|2 – 2| = | 6-2| = 4* *d23 = | 2 – 6 | + |2 – 3.33| = 5.33*
d13 = |2 – 6| = | 6- 3.33 | = 6.67 *d24= | 2 – 8 | + | 2 - 6) = 10*
. *d14= |2 – 8 | + | 6 – 6| = 6* *d25 = | 2 –9 | = | 6 – 6 | = 7*
. *d15 = | 2 – 9| + | 6 – 2| = 11* *d34 = | 6 –8 | + | 3.33 2 – 6| = 4.67*
. *D35 = | 8 – 9| + | 3.33 – 2| = 4.33* *d45 = | 8 -9 | + |6 – 2| = 5*

F\t	1	2	3	4	5
1	-	1	1	1	1
2	1	-	1	1	1
3	1	1	-	1	1
4	1	1	1	-	1
5	1	1	1	1	-

Total cost matrix = flow matrix * distance matrix * cost matrix

. cost matrix

F\t	1	2	3	4	5
1	-	5	2	4	0
2	0	-	2	5	0
3	2	0	-	0	5
4	3	0	1	-	0
5	0	0	2	0	-

F\t	1	2	3	4	5
1	-	4	6.67	6	11
2	4	-	5.33	10	7
3	6,67	5.33	-	4.67	4.33
4	6	10	4.67	-	5
5	11	7	4.33	5	-

F\t	1	2	3	4	5
1	-	20	13.3	24	0
2	0	-	10.66	50	0
3	13.34	0	-	0	21.65
4	18	0	10	-	0
5	0	0	8.66	0	-

Flow matrix distance matrix total cost matrix

Total cost = 20+ 13.3+ 24+10.66 + 50 +13.34+21.65 + 18+ 10+ 8.66 = 189.66

Alternate-8: For interchanging dept-4 and department-5 centroids will change as follows

X1, y1 = (2, 6)
X2, Y2 = (2, 2)
x3, y3 = (7, 2)
x4, y4 = (6, 6)
x5, y5 = (9,6)

|<-4->| 2 |<-4->|

___
4

____
d13 = |2 –
. *d14= |2 –*
. *d15 = | 2*

1	4	5
2	3	

Alt-layout 8

d12= *|2 – 2| = | 6-2| = 4* *d23 = | 2 – 7 | + |2 – 2| =5*
7| = | 6- 2 | = 9 *d24= | 2 – 6 | + | 2 - 6) = 8*
6 | + | 6 – 6| = 4 *d25 = | 2 –9 | = | 2 – 6 | = 11*
– 9| + | 6 – 6| = 7 *d34 = | 7 –6 | + | 2 – 6| = 5*
. *d35 = | 7 – 9| + | 2 – 6| = 6* *d45 = | 6 -9 | + |6 – 6| = 3*

F\t	1	2	3	4	5
1	-	5	2	4	0
2	0	-	2	5	0
3	2	0	-	0	5
4	3	0	1	-	0
5	0	0	2	0	-

F\t	1	2	3	4	5
1	-	4	9	4	7
2	4	-	5	8	11
3	9	5	-	5	6
4	4	8	5	-	3
5	7	11	6	3	-

F\t	1	2	3	4	5
1	-	1	1	1	1
2	1	-	1	1	1
3	1	1	-	1	1
4	1	1	1	-	1
5	1	1	1	1	-

F\t	1	2	3	4	5
1	-	20	18	16	0
2	0	-	10	40	0
3	18	0	-	0	30
4	12	0	5	-	0
5	0	0	12	0	-

Flow matrix distance matrix cost matrix total cost matrix

Total cost = 20+ 18+16+10 +40 + 18 + 30 + 12 + 5 + 12 = 181

Tabulating all total cost for all possible alternatives.

S No	Department Pairs	Interchanging criteria	Total cost
1	1 and 2	Common border	205
2	1 and 3	Not possible	
3	1 and 4	Equal area	193
4	1 and 5	Common border	221
5	2 and 3	Common border	203
6	2 and 4	Equal area	201
7	2 and 5	Not possible	
8	3 and 4	Common border	170 min 7 optimum layout
9	3 and 5	Common border	189
10	4 and 5	Common border	181

It is observed from table that exhaling dept-3 and depart-4 will optimum total cost = 170
The optimum layout is

2.9 AUTOMATED LAYOUT DESIGN PROGRAM (ALDEP)

ALDEP belongs to the construction type program, which builds the layout without using the existing layout. It also considered as an improvement program due to the evaluation process of accepting or rejecting the given layout. It builds the layout by placing the most related departments, size required and based on the closeness rating (ir A or E) of A, E, I, O, U, X. it adds continuously the other departments till the placement of all activities has been completed. This process is continued till all the departments are placed in he layout and no department should be available for placing with high closeness rating. At this stage , score is computed for layout in terms of numerical values. This procedure is repeated for several times and evaluates the best layout with maximum layout score.

2.10 INPUT REQUIREMENTS OF ALDEP:

The basic information required for ALDEP algorithm is summarized as below.

- The number of departments in the layout.
- Area of each department.
- Length and width of layout
- The values of closeness for the pairs of department based on Relationship chart.
- Minimum Department Preference (MDP) value
- Sweep width.
- The least possible score for an acceptable layout.
- Total number of layouts to be generated.
- Building outline and scale of layout printout.
- The location and size of each prohibited area (if present)

2.11 STEP BY STEP PROCEDURE OF ALDEP ALGORITM :

The procedure for executing ALDEP program is described below.

STEP-1 Give the input in following manner.

- The number of departments in the layout.

- Area of each department.
- Length and width of layout
- The values of closeness for the pairs of department based on Relationship chart.
- Minimum Department Preference (MDP) value
- Sweep width.
- Number of iterations to be carried out (N)
- Current iteration number (I)
- Location and size of fixed department (if present)
- Score of the current layout.
- The least possible score for an acceptable layout.
- Total number of layouts to be generated.
- Building outline and scale of layout printout.
- The location and size of each prohibited area if present

STEP-2: Consider a appropriate scale for one unit square and calculate no of squares for all the departments. Consider appropriate scaled layout such that total no of squares are within the layout area.

Step-3 : Select a department randomly and place it in the layout:. Perform placement of departments considering sweep width criteria staring from top left corner by filling equilant no of squares.

STEP-4: After placing the randomly selected department in the layout, scan the relationship chart and devide the nonselected departments into category-A and category-B.scan the relationship chart following condition

Category-A ; { depts. Whose REL <MDP or 4 } REL < 4

Category-B : { depts. Having REL >= MDP or 4 } REL >=4

STEP-4: check for the availability of non selected department in category –B

- If it is non empty, then choose a non selected department in category –B itself corresponding to maximum REL value and place that dept in the layout.
  If it is empty, then select a department randomly from category –A, and place it in the layout.

STEP-5: check for e placement of all departments n the layout. If an department is found to be unplaced, follow the STEP-3, otherwise determine the score for the layout.

STEP-6: check whether the computed score of the layout is higher than the current best layout

If yes, call the new layout as the current best layout and save corresponding score.

STEP-7: check for the current iteration number ie I=N. I ys , print the current best layout as final layout and its corresponding score as a final score.

If no, increase the iteration number as (I=I+1) and follow step-2.

2.12 ADVANTAGES OF ALDEP: are as follows

- It can affix the particular locations which are available under certain limits.
- The solution or result obtained from ALDEP is available within t definite area.
- The possibility of developing several replacements in order to obtain the optimum solution of layout.
- The possibility to have majority of inter-relationships.
- The capacity of degenerating multiple levels of layouts.

2.13 DISADVANTAGES/ LIMITATIONS OF ALDEP:

- It does not calculate the movement cost.
- Honor can not be given to unpleasant relationships.
- The method of determining score is suspicious or undefined.

- The process of evaluating production is complicated.
- It does not consider the mandatory space configuration.
- Restricted to only up to 63 departments.
- It does not calculate the movement cost.
- Honor cannot be given to unpleasant relationships.
- The method of determining score is suspicious or undefined.
- The process of evaluating production is complicated.
- It does not consider the mandatory space configuration.
- Restricted to only unto 63 departments.

2.14 Problem of ALDEP:

Determine the best layout using ALDEP algorithm for following data

Area of departments		
Dept.	**Function**	**Area (in Sq.m)**
1	Receiving	12,000
2	Milling	8,000
3	Press	6,000
4	Screw machine	12,000
5	Assembly	8,000
6	painting	12,000
7	shipping	12,000
Total		70,0000

RELATIONSHIP CHART							
	1	2	3	4	5	6	7
1	-	E	O	I	O	U	U
2	E	-	U	E	I	I	U
3	O	U	-	U	U	O	U
4	I	E	U	-	I	U	U
5	O	I	U	I	-	A	I
6	U	I	O	U	A	-	E
7	U	U	U	U	I	E	-

Number of departments :7 ,
Minimum department preference (MDP) value , I = 4
Sweep width = 2 , Number of iterations to be performed , N=2**.**

REL CODE	**REL VALUE**
A	64 (4^3)
E	16 (4^2)
I	4 (4^1)
O	1 (4^0)
U	0
X	-4

Solution To ALDEP problem;

STEP-1. Give the input in following manner.

- The number of departments in the layout.
- Area of each department.
- Length and width of layout
- The values of closeness for the pairs of department based on Relationship chart.
- Minimum Department Preference (MDP) value
- Sweep width.
- Number of iterations to be carried out (N)
- Current iteration number (I)
- Location and size of fixed department (if present)
- Score of the current layout.
- The least possible score for an acceptable layout.
- Total number of layouts to be generated.
- Building outline and scale of layout printout.
- The location and size of each prohibited area if present

Consider area per square = 400 sq. m

Area of departments		Scale	No. of
Function	Area (in Sq.m)	1 square=400sqm	squares
Receiving	12,000	400	30
Milling	8,000	400	20
Press	6,000	400	15
Screw machine	12,000	400	30
Assembly	8,000	400	20
painting	12,000	400	30
shipping	12,000	400	30
Total	70,0000		175

For dept-1 no of squares = dept-1 area /400 = 12000/400:=30 squares
For det-2 : 8000/400: 20,
for dept-3= 6000/400=1
Scale of Layout = length and width of layout
Assume as 12 * 15 = 180 Sq. units
MDP value , I = 4
Swep width = 2

STEP-2: select a department randomly, to construct a layout. So randomly selected dept-4, which has 1200 sq.m area of 30 squares. Perform placement of 30 squares pertaining detp-4.

Placement stars from upper left corner and moves to bottom, then from bottom to upper edge and continues. The number of columns to be filled depends upon the sweep width. ie two columns are filled simultaneously.

4	**4**												
4	**4**												
4	**4**												
4	**4**												
4	**4**												
4	**4**												
4	**4**												
4	**4**												
4	**4**												
4	**4**	**4**	**4**										
4	**4**	**4**	**4**										
4	**4**	**4**	**4**										

RELATIONSHIP CHART

	1	2	3	4	5	6	7
1	-	E	O	I	O	U	U
2	E	-	U	E	I	I	U
3	O	U	-	U	U	O	U
4	I	E	U	-	I	U	U
5	O	I	U	I	-	A	I
6	U	I	O	U	A	-	E
7	U	U	U	U	I	E	-

STEP-3: Scanning the relationship chart and unselected depts in to category-A, category-B

Unselected department	1	**2**	3	5	6	7
REL with selected dept-4	I=4	**E=16**	U=0	I=4	U=0	U=0

Catgory –A = { dep-3, dept-6, dept-7 } for REL < MDP ie 4

Category –B = { dept-1, dept-2 max, dept-5 } for REL >= 4
STEP-4: Since category-B is non-empty set proceed to step-4.

STEP-5: if category-B is a non-empty set , select a department which has maximum REL value ie dept-2 has max REL value =16, so **dept-2** is selected. As dept-2 has an area of 8000 sq.m which can occupy 20 squares.
Placement of dept-2 in layout is as shown below

4	4	2	2	2	2										
4	4	2	2	1	1										
4	4	2	2	1	1										
4	4	2	2	1	1										
4	4	2	2	1	1										
4	4	2	2	1	1										
4	4	2	2	1	1										
4	4	2	2	1	1										
4	4	2	2	1	1	1	1								
4	4	4	4	1	1	1	1								
4	4	4	4	1	1	1	1								
4	4	4	4	1	1	1	1								

RELATIONSHIP CHART							
	1	2	3	4	5	6	7
1	-	E	O	I	O	U	U
2	E	-	U	E	I	I	U
3	O	U	-	U	U	O	U
4	I	E	U	-	I	U	U
5	O	I	U	I	-	A	I
6	U	I	O	U	A	-	E
7	U	U	U	U	I	E	-

STEP-6: As all the departments are not placed , proceed with step-3.

STEP-3: Scanning the relationship chart and unselected depts in to category-A, category-B

Unselected department	3	5	6	7
REL with selected dept-1	O=1	O=1	U=0	U=0

Catgory –A = { dep-3, DEPT-5, DEPT-6, dept-7 } for REL < MDP ie 4

Category –B = { } for REL >= 4 empty set

STEP-4: Since category-B is empty set, Select a department randomly from category-A and place in the layout.
Select dept-6 randomly and place in the layout which has 12000 sq.m and can accupy 30 squares.
Placement of dept-6 in layout is as shown below

4	4	2	2	2	2	6	6	6	6					
4	4	2	2	1	1	6	6	6	6					
4	4	2	2	1	1	6	6	6	6					
4	4	2	2	1	1	6	6	6	6					
4	4	2	2	1	1	6	6	6	6					
4	4	2	2	1	1	6	6	6	6					
4	4	2	2	1	1	6	6	6	6					
4	4	2	2	1	1	6	6							
4	4	2	2	1	1	1	1							
4	4	4	4	1	1	1	1							
4	4	4	4	1	1	1	1							
4	4	4	4	1	1	1	1							

STEP-5: As all the departments are not placed , proceed with step-3

STEP-3: Scanning the relationship chart and unselected depts in to category-A, category-B

Unselected department	3	**5**	7
REL with selected dept-6	O=1	**A=64 max**	E=16

Catgory –A = { dep-3 } for REL < MDP ie 4

Category –B = { dept-5, dept-7 } for REL >= 4 which s non-empty set proceed to Step-4

STEP-4: if category-B is a non-empty set , select a department which has maximum REL value ie dept-5 has max REL value =64, so **dept-5** is selected. As dept-5 has an area of 8000 sq.m which can occupy 20 squares. Placement of dept-5 in layout is as shown below

RELATIONSHIP CHART							
	1	2	3	4	5	6	7
1	-	E	O	I	O	U	U
2	E	-	U	E	I	I	U
3	O	U	-	U	U	O	U
4	I	E	U	-	I	U	U
5	O	I	U	I	-	A	I
6	U	I	O	U	A	-	E
7	U	U	U	U	I	E	-

4	4	2	2	2	2	6	6	6	6					
4	4	2	2	1	1	6	6	6	6					
4	4	2	2	1	1	6	6	6	6					
4	4	2	2	1	1	6	6	6	6					
4	4	2	2	1	1	6	6	6	6					
4	4	2	2	1	1	6	6	6	6					
4	4	2	2	1	1	6	6	6	6					
4	4	2	2	1	1	6	6	5	5	5	5			
4	4	2	2	1	1	1	1	5	5	5	5			
4	4	4	4	1	1	1	1	5	5	5	5			
4	4	4	4	1	1	1	1	5	5	5	5			
4	4	4	4	1	1	1	1	5	5	5	5			

STEP-6: As all the departments are not placed, proceed with step-3.

STEP-3: Scanning the relationship chart and unselected depts in to category-A, category-B

Unselected department	3	7
REL with selected dept-5	U=0	I=4

Catgory –A = { dep-3 } for REL < MDP ie 4

Category –B = { dept-7 } for REL >= 4 which s non-empty set proceed to Step-4

STEP-4: if category-B is a non-empty set , select a department which has maximum REL value ie dept-7 has max REL value =4, so dept-**7** is selected. As dept-7 has an area of 12000 sq.m which can occupy 30 squares. Placement of dept-7 in layout is as shown below

4	4	2	2	2	2	6	6	6	6	7	7	7	7	
4	4	2	2	1	1	6	6	6	6	7	7	7	7	
4	4	2	2	1	1	6	6	6	6	7	7	7	7	
4	4	2	2	1	1	6	6	6	6	7	7	7	7	
4	4	2	2	1	1	6	6	6	6	7	7	7	7	
4	4	2	2	1	1	6	6	6	6	7	7	7	7	
4	4	2	2	1	1	6	6	6	6	7	7	7	7	
4	4	2	2	1	1	6	6	5	5	5	5	7	7	
4	4	2	2	1	1	1	1	5	5	5	5			
4	4	4	4	1	1	1	1	5	5	5	5			
4	4	4	4	1	1	1	1	5	5	5	5			
4	4	4	4	1	1	1	1	5	5	5	5			

RELATIONSHIP CHART							
	1	2	3	4	5	6	7
1	-	E	O	I	O	U	U
2	E	-	U	E	I	I	U
3	O	U	-	U	U	O	U
4	I	E	U	-	I	U	U
5	O	I	U	I	-	A	I
6	U	I	O	U	A	-	E
7	U	U	U	U	I	E	-

At last dept-3 is remaining in the layout. Hence dept-3 is placed, which has 6000 sq.m d can occupy 15 squares. Placement of dept-3 in layout is as shown below

4	4	2	2	2	2	6	6	6	6	7	7	7	7	0
4	4	2	2	1	1	6	6	6	6	7	7	7	7	0
4	4	2	2	1	1	6	6	6	6	7	7	7	7	0
4	4	2	2	1	1	6	6	6	6	7	7	7	7	0
4	4	2	2	1	1	6	6	6	6	7	7	7	7	0
4	4	2	2	1	1	6	6	6	6	7	7	7	7	3
4	4	2	2	1	1	6	6	6	6	7	7	7	7	3
4	4	2	2	1	1	6	6	5	5	5	5	7	7	3
4	4	2	2	1	1	1	1	5	5	5	5	3	3	3
4	4	4	4	1	1	1	1	5	5	5	5	3	3	3
4	4	4	4	1	1	1	1	5	5	5	5	3	3	3
4	4	4	4	1	1	1	1	5	5	5	5	3	3	3

In final layout empty space is represented with zero square which represent space for four cells
STEP-6: since all the departments are placed in the layout, proceed to step-7.

REL CODE	REL VALUE
A	64 (4^3)
E	16 (4^2)
I	4 (4^1)
O	1 (4^0)
U	0
X	-4

STEP-7: Evaluate the score of layout. It is calculated as the sum of REL values of various side by side pairs of departments n the layout.
The score of layout is tabulated as shown below.

Side by side pair of dpts	**REL code**	**REL Value**
4-2	E	16
4-1	I	4
2-1	E	16
2-6	I	4
1-6	U	0
1-5	O	1
6-7	E	16
5-6	A	64
5-7	I	4
5-3	U	0
7-3	U	0
Total	605	125

the score based on two-way relation ship is 125*2= 250
STEP-8: The first layout is obtained. Consider this layout as the best current layout.
STEP-9: Increase the iteration number by 1 (ie I = 1+1 =2, more iterations can be performed but since N=2 continue to step-10.
STEP-10. Print the current layout.

4	**4**	2	2	2	2	6	6	6	6	7	7	7	7	0
4	**4**	2	2	**1**	**1**	6	6	6	6	7	7	7	7	0
4	**4**	2	2	**1**	**1**	6	6	6	6	7	7	7	7	0
4	**4**	2	2	**1**	**1**	6	6	6	6	7	7	7	7	0
4	**4**	2	2	**1**	**1**	6	6	6	6	7	7	7	7	0
4	**4**	2	2	**1**	**1**	6	6	6	6	7	7	7	7	3
4	**4**	2	2	**1**	**1**	6	6	6	6	7	7	7	7	3
4	**4**	2	2	**1**	**1**	6	6	**5**	**5**	**5**	**5**	7	7	3
4	**4**	2	2	**1**	**1**	**1**	**1**	**5**	**5**	**5**	**5**	3	3	3
4	**4**	**4**	**4**	**1**	**1**	**1**	**1**	**5**	**5**	**5**	**5**	3	3	3
4	**4**	**4**	**4**	**1**	**1**	**1**	**1**	**5**	**5**	**5**	**5**	3	3	3
4	**4**	**4**	**4**	**1**	**1**	**1**	**1**	**5**	**5**	**5**	**5**	3	3	3

2.15 COMPUTERIZED RELATION SHIP LAYOUT PLANNING (CORELAP)

Computerized Relationship Layout Planning algorithm is a chart for construction of layout. The layout in CORELAP can be generated by locating the rectangular shaped departments, if departmental area and layout scale allows their representation in a rectangular form. CRELAP has the capacity to manage up to 70 number of departments.

2.16 INPUT REQUIREMENTS OF CORELAP:

- The Input requirements of CORELAP algorithm is as follows
- The number of departments in the layout.
- Area of each department.
- Length and width of layout.
- The closeness Relationship value based on Relationship chart. (REL chart)
- Scale of output
- Building length to width ratio
- Department pre-assignment.

2.17 STEP-BY-STEP PROCEDURE OF CORELAP:

The step by step procedure of CORELAP algorithm is as follows.

STEP-1 : Provide basic input data in the following manner.

- The number of departments in the layout.
- Area of each department.
- Length and width of layout.
- The closeness Relationship values based on Relationship chart. (REL chart)
- Scale of output
- Building length to width ratio
- Department pre-assignment

STEP-2: consider scale as 1 square = 600 sq.m Compute no. of square units for all the departments.
no of squares = dept. area /Area per square in layout

STEP-3: By using R EL- chart, compute total closeness rating for all the departments

department	Closeness rating	TCR
1	E+o+I+0+U+U=5+3+4+3+2+2	19
2	E+U+E+I+I+U= 5+2+%+4+4+2	22
3	O+U+U+U+O+U=3+2+2+2+3+2	14
4	I+E+U+I+U+U=4+5+2+4+2+2	19
5	O+I+U+I+A+I= 3+4+2+4+6+4	23 max
6	U+I+O+U+A+E= 2+4+3+2+6+5	22
7	U+U+U+U+I+E= 2+2+2+2+4+5	17

STEP-4:Select department with highest TCR value. The selected department occupy 1 square and it is placed in the centre of layout matrix.

STEP-5. Check the closeness relationship of first selected dept with other departments. And note the corresponding closeness value .now select maximum REL value dept.

Closeness of dept-5 with	**Dept-1**	**Dep-2**	**Dept-3**	**Dept-4**	**Dept-6**	**Dept-7**
REL	O	I	U	I	**A**	I
Closeness value	3	4	2	4	**6 max**	4

STEP-:5 check the closeness of un selected dpts with selected depts.

Department	1	**2**	3	4	7
Closeness of 1st selected dept with Closeness value	O	**I**	U	I	I
	3	**4**	2	4	4
Closeness of 2nd selected dept with closeness value	U	**I**	O	U	E
	2	**4**	3	2	5 max

Select that department which has maximum REL Value as 3rdseleced dept.

STEP-7: Repeat the above procedure with unassigned departments

Department	1	**2**	3	4
Closeness of 1st selected dept with Closeness value	O	I	U	I
	3	4 max	2	4 max
Closeness of 2nd selected dept with closeness value	U	I	O	U
	2	4	3	2
Closeness of 3rd selected dept with closeness value	U	U	U	U
	2	**2**	2	2

In case if maximum REL value happens for more than one department we have to follow following procedure.

I. If REL is same, them compare TCR for those departments. Then select that department which has higher TCR value as shown in following table.

Department	REL Value	TCR value
Dept-2	5	22 max select it
Dept-4	5	19

II. If REL Value, and TCR Value is same , then check their areas, select that department which has maximum area.

Department	REL Value	TCR value	Area (sq.m)
Dept-1	4	19	12000 select it
Dept-4	5	19	8000

I. In case REL are equal, TCR are Equal and Areas also equal, then select any depart from unassigned department randomly

Department	REL Value	TCR value	Area (sq.m)	
Dept- 6	4	22	12000	SELECT DEP-6, or dept-7 randomly
Dept-7	4	22	12000	

Apply above procedure till all the departments are selected.
Select 1st priority dept as a first in placement order
Select 2nd priority dept as a second in placement order
Select 3rdriorityrepartment as a third in placement order
Select 4th priority dept. as a fourth in placement order.
Select 5th priority dept as a fifth in placement order

FOR PLACEMENT OF DEPARTMENTS**: t**he following procedure is to be follows

1st selected Dept-5 which has area of one square is placed at the center of 7 *5 matrix as shown below.

							5							

Step-2: Dept-6 is selected as second in placement order which can occupy two squares.
The placement odept- can be as follows.

66
5

5
66
Alternate-1

6 5
6
alternate-2

6 5
6
alternate-3

56
6
alternate-4

Consider the weighted closeness value for CORELAP as shown in following table
Calculate the placement rating = sum of weighted closeness rating
Between entering and its neighbor
Copute the weighted rating of all alternatives, select that alternate which has maximum score.

since all weighted ratings are equal , select alternate-1 randomly
step-3: similarly we above procedure , till you place all departments efficiently.

Step-4; in case weighted ratings are same for any two or alternatives, select any one randomly.
Step-5:complete to place all the departments and final layout is as shown below. Then calculate the total score of the layout

				4	**1**	**1**	**3**						
				4	**2**	**6**	**6**						
					7	**7**	**5**						

Total score of layout = sum of product of numerical closeness value and length of shortest path between all pairs of depts.= ∑ (closeness rating * lengthy of shortest distance
Now the total score is computed to all pairs of departments and above procedure can be repeated by considering different scale value and optimum layout can be obtained.

2.18 PROBLEM OF CORELAP:

Develop a layout using CORELAP for the following problem, for which the layout and are requirements are shown in the table given below.

departments	
department	**Area (in Sq.m)**
1	12,000
2	8,000
3	6,000
4	12,000
5	8,000
6	12,000
7	12,000
Total	70,0000

RELATIONSHIP CHART							
	1	2	3	4	5	6	7
1	-	E	O	I	O	U	U
2	E	-	U	E	I	I	U
3	O	U	-	U	U	O	U
4	I	E	U	-	I	U	U
5	O	I	U	I	-	A	I
6	U	I	O	U	A	-	E
7	U	U	U	U	I	E	-

Closeness values A= 6, E=5, I=4 , O=3 , U=2 X=1

I. The number of departments in the layout.
II. Area of each department.
III. Length and width of layout.
IV. The closeness Relationship value based on Relationship chart. (REL chart)
V. Scale of output
VI. Building length to width ratio
VII. Department pre-assignment.

STEP-1 : Provide basic input data in the following manner.

- The number of departments in the layout.
- Area of each department.
- Length and width of layout.
- The closeness Relationship values based on Relationship chart. (REL chart)
- Scale of output
- Building length to width ratio
- Department pre-assignment
-

Closeness Relationship	Weighted rating
Preassigned	729 (3^6)
A	243 (3^5)
E	81 (3^4)
I	27 (3^3)
O	9 (3^2)
U	0
X	-729 (-3^6)

STEP-2: consider scale as 1 square = 600 sq.m
Compute no. of square units for all the departments.
no of squares = dept. area /Area per square in layout

departments		Scale	No. of
department	Area (in Sq.m)	1 square=6000 sqm	squares
1	12,000	6000	2
2	8,000	6000	1
3	6,000	6000	1
4	12,000	6000	2
5	8,000	6000	1
6	12,000	6000	2
7	12,000	6000	2
Total	70,0000		11

STEP-3: By using R EL- chart, compute total closeness rating for all the departments

department	Closeness rating	TCR
1	E+o+I+0+U+U=5+3+4+3+2+2	19
2	E+U+E+I+I+U= 5+2+%+4+4+2	22
3	O+U+U+U+O+U=3+2+2+2+3+2	14
4	I+E+U+I+U+U=4+5+2+4+2+2	19
5	O+I+U+I+A+I= 3+4+2+4+6+4	23 max
6	U+I+O+U+A+E= 2+4+3+2+6+5	22
7	U+U+U+U+I+E= 2+2+2+2+4+5	17

STEP-4:Select department with highest TCR value. Dept-5 has maximum TCR value ie 24, so dept-5 is selected and can occupy 1 square and it is placed in the centre of layout matrix.
STEP-5. Check the closeness relationship of selected dept-5 with other depts. ie dept-1, dept-2, dept-3, dept,4, dept-6, dept- and select maximum REL value dept. ie dept-6.

Closeness of dept-5 with	Dept-1	Dep-2	Dept-3	Dept-4	**Dept-6**	Dept-7
REL	O	I	U	I	**A**	I
Closeness value	3	4	2	4	**6 max**	4

Dept-6 is selected as second placement order as dept-6 has maximum REL value.
STEP-:5 cck e closeness of unselected dpts with selected depts. Ie dept-5, dept-6

department	1	**2**	3	4	7
Closeness of dept-5 with	O	**I**	U	I	I
Closeness value	3	**4**	2	4	4
Closeness of dept-6 with	U	**I**	O	U	E
closeness value	2	**4**	3	2	5 max

Since dept-7 has maximum closeness value with respect to dept-6 ie 5, select ept-7 as 3rd priority in placement order.
STEP-7: Repeat the above procedure with unassigned departments (dept-1, dept-2, dept-3, dept-4)

department	1	2	3	4
Closeness of dept-5 with Closeness value	O	I	U	I
	3	4 max	2	4 max
Closeness of dept-6 with closeness value	U	I	O	U
	2	4	3	2
Closeness of dept-7 with closeness value	U	U	U	U
	2	2	2	2

Ept-2 and dept-4 have highest closeness value (ie I=4) with dept-5.
In this ase both pt-2, dept-4 as equal closeness value of 4. Then the department with high TCR is selected.

Department	TCR value
Dept-2	22 max
Dept-4	19

Dept-2 has highest TCR ie22 , hence dept-2 is selected as fourth in placement order.
STEP-8: Rpeat this procedure with un assigned dets (ie dept-1, dept-3, dept-4) for assigned depts. (ie dept-5dept-6, dept-7, dept-2)

department	1	3	4
Closeness of dept-5 with Closeness value	O	U	I
	3	2	4
Closeness of dept-6 with closeness value	U	O	U
	2	3	2
Closeness of dept-7 with closeness value	U	U	U
	2	2	2
Closeness of dept-2 with closeness value	E	U	E
	5 max	2	5 max

Dept-1 and dept-4 have highest closeness value (ie E = 5) with dept-2. Here closeness value is equal for dept-1 and dept-4, then compare TCR value of these departments.

Department	TCR value
Dept-1	19
Dept-4	19

Here the TCR values also equal for dept-1 and dept-4. Then compare the department area

Department	area
Dept-1	12000sqm
Dept-4	12000sqm

In this case the closeness value of dept-1 and dept-4 are equal ie =5
The tcr value of dept-1 and dept-4 are equal ie = 19
The Area of dept-1 and dept-4 are equal ie =12000 sqm
When all the parameters are equal , select a department randomly among dept-1 and dept-4. Hence dept-1 is selected randomly.
STEP-9: Repeat the same procedure for unassigned departments ie dept-3, dept-4

department	3	4
Closeness of dept-5 with Closeness value	U	I
	2	4
Closeness of dept-6 with closeness value	O	U
	3	2

Closeness of dept-7 with closeness value	U	U
	2	2
Closeness of dept-2 with closeness value	U	E
	2	5 max
Closeness of dept-1 with h closeness value	O	I
	3	4

DEPT-4 has highest closeness value 9 ie E=5) with dept-2.

Hence dept-4 is selected as X^{th} in placement order,
STEP-7.: since the only left out department is dept-3. Hence consider dept-3 as seventh (Last) in placement order.
Solution:
Dpt-5 is selected as first in placement order.
Dpt-6 is selected as second in placement order.
Dpt-7 is selected as third in placement order.
Dpt-2 is selected fourth in placement order.
Dpt-1 is selected fifth in placement order.
Dpt-4 is selected sixth in placement order.
Dpt-3 is selected seventh in placement order.

PLACEMENT OF DEPARTMENTS IN LAYOUT:
Dept-5 is selected first which 800o sq.m area nd can occupy one square. Thi dept-5 is placed at the cente of 7 *5 matrix as shown below.

						5							

Step-2: Dept-6 is selected as second in placement order which can occupy two squares.
The placement of dept-6 can be as follows.

66 5 | 5 66 | 6 5 6 | 56 6

Alternate-1 alternate-2 alternate-3 alternate-4

Consider the weighted closeness value for CORELAP as shown in following table
Calculate the placement rating = sum of weighted closeness rating

ClosenesRelations hip	Weighted rating
Preassigned	729 (3^5)
A	243 (3^5)
E	81 (3^4)
I	27 (3^3)
O	9 (3^2)
U	0
X	-729 (-3^5)

Calculate the placement rating = sum of weighted closeness rating
Between entering and its neighbour

alt-1) weighted rating of dept-6 with 5 = A= 243
alt-2) weighted rating of dept-6 with 5 = A = 243

		6	**6**
			5

alt-3) weighted rating of dept-6 with 5 = A =243
alt-4) weighted rating of dept-6 with 5 = a= 243
since all weighted ratings are equal , select alternate-1 randomly

66 5

STEP-3: dept-7 is selected as third in placement order, which has n area of 1200 sq.m and can occupy two squares , dept-7 can be placed adjacent todept-6 and dept-5 in different alternatives as follows.

66 667 66 66
5 57 775 7 5
7

Alternate-1 alternate-2 alternate-3 alternate-4

alt-1) weighted rating of dept-7 with dept-6 = E = 81

alt-2) weighted rating of dept-7 with dept-6 = E = 81
weighted rating of dept-7 with dept-5 = I = 27→ 108

alt-3) weighted rating of dept-7 with dept-6 = E= 81
weighted rating of dept-7 with dept-5 = I= 27→ 108

alt-4) weighted rating of dept-7 with dept-6 = E= 81
weighted rating of dept-7 with dept-5 = I = 27→108

since all weighted ratings are equal ie 108, , select alternate-3 arrangement randomly

66
775

		6	**6**
	7	**7**	**5**

STEP-3: dept-2 is selected as fourth in placement order, which has an area of 8000 sq.m and can occupy one square , dept-2 can be placed adjacent to dept-5 and dept-6, dept-7 in different alternatives as follows.

266	66	66
775	775	7752
	2	
Alternate-1	alternate-2	alternate-3alternate-3

alt-1) weighted rating of dept-2 with dept-6 = I = 27
weighted rating of dept-2 with dept-7= U = 1→28 max

alt-2) weighted rating of dept-2 with dept-7 = U = 1

alt-3) weighted rating of dept-2 with dept-5 = I= 27
select aternate-1 arrangement.
Dept-2 is placed adjacent to dept-6 and dept-7 since the

Placement rating is maximum. The layout at this stage is :

266
775

	2	**6**	**6**
	7	**7**	**5**

STEP-5: next dept-1 is selected as fifth in placement order. It has an area of 12000 sq.m which can occupy two squares.
Dept-1 can be placed in following alternate ways.

	11			
2661	**266**	12661	1266	266
7751	**77 5**	775	177 5	17751
Alternate-1	alternate-2	alternate-3	alternate-4	Alternate-5

alt-1) weighted rating of dept-1 with dept-6 = U = 1
weighted rating of dept-1 with dept-5 =O = 9 → 10

alt-2) weighted rating of dept-1 with dept-6 = U = 1
weighted rating of dept-1 with dept-2 = E= 81→ 82

alt-3) weighted rating of dept-1 with dept-6 = U= 1
weighted rating of dept-1 with dept-2= E= 81→ 82

alt-4) weighted rating of dept-1 with dept-2 = E= 81
weighted rating of dept-1 with dept-7 = U = 1→82

alt-5) weighted rating of dept-1 with dept-5 = O= 9
weighted rating of dept-1 with dept-7 = U = 1→10

since all weighted ratings are equal ie 108, , for alt-2, alt-3,alt-4 ,
select alternate-1 arrangement randomly

	1	**1**	
	2	**6**	**6**
	7	**7**	**5**

11
266
775

STEP-6: now dept-4 is selected as sixth in placement order. It has an area of 12000 sq.m which can occupy two squares.

Dept-4 can be placed in following alternate ways.

411	11	11	11	114
4266	4266	266	2664	2664
775	477 5	775	77 54	775

Alternate-1 alternate-2 alternate-3 alternate-4 Alternate-5
Alt-1 Weighted rating of [(dept-4 with 1) +) dept-4 with 2] = I +E = 27+81 = 108 maximum
Alt-2 : weighted rating of [(dept-4 with 2) +) dept-4 with 7] = E+ U = 81+1 = 82
Alt-3 : weighted rating of [(dept-4 with 7) +) dept-4 with 5] = U+ I = 1+27 =28
Alt-4 : weighted rating of [(dept-4 with 6) +) dept-4 with 5] = U+I = 1 +27 = 28
Alt-5 : weighted rating of [(dept-4 with 1) +) dept-4 with 6] = I+ U =27+1 = 28
Rom the above evaluation, aleternateve-1 is selected.

STEP-6: finally dept-3 is selects as seventh in placement order. It hs an area of 6000 sq,m and can occupy one square. Dept-3 can be placed in following ways.

411	4113
4266	4266
3775	77 5

Alternate-1 alternate-2
Alt-1 Weighted rating of [(dept-3 with 4) +) dept-3 with 7] = U +U = 1 + 1= 2
Alt-2 : weighted rating of [(dept-3 with 1) +) dept-3 with 6] = I + I = 9+9 = 18

from the above evaluation, aleternateve-2 is selected.
Dept-3 is placed adjacent to dept-1 and dept-6. As shown below.

				4	1	1	3							
				4	2	6	6							
					7	7	5							

All the departments have been placed in layout.
Total score of layout = sum of product of numerical closeness value and length of shortest path between all pairs of depts.= ∑ (closeness rating * lengthy of shortest distance
Now the total score is computed to all pairs of departments and are tabulated as follows.

Department		**distance**	**closeness**		**Score = Distance*value**
from	to		grade	value	
1	2	0	-	-	-

1	3	0	-	-	-
1	4	0	-	-	-
1	5	2	O	3	6
1	6	0	-	-	-
1	7	1	U	2	2
2	3	2	U	2	4
2	4	0	-	-	-
2	5	2	I	4	8
2	6	0	-	-	-
2	7	0	-	-	-
3	4	2	U	2	4
3	5	1	U	2	2
3	6	0	-	-	-
3	7	2	U	2	4
4	5	3	I	4	12
4	6	1	U	2	2
4	7	1	U	2	2
5	6	0	-	-	-
5	7	O	-	-	-
6	7	0	-	-	-
TOTAL SCORE					**46**

The total score is 46, the above procedure can be repeated by considering different scale value and optimum layout can be obtained

closeness value and length of shortest path between all pairs of depts.= ∑ (closeness rating * lengthy of shortest distance

Now the total score is computed to all pairs of departments and are tabulated as follows.

Department		**distance**	**closeness**		**score**
from	**to**		**grade**	**value**	
1	5	2	O	3	6
1	7	1	U	2	2
2	3	2	U	2	4
2	4	0	-	-	-
2	5	2	I	4	8
3	4	2	U	2	4
3	5	1	U	2	2
3	7	2	U	2	4
4	5	3	I	4	12
4	6	1	U	2	2
4	7	1	U	2	2
TOTAL SCORE					**46**

The total score is 46, the above procedure can be repeated by considering different scale value and optimum layout can be obtained.

2.20 GROUP TECHNOLOGY (CELLULAR) LAYOUT:

Group Technology (Cellular) layout: is a type of layout where the machined are arranged in the form of cells. Each cell may function either as a product layout within large shop or a process layout. The cells in a cellular layout are engaged in producing single parts of same machine having same features and those requiring the same production setting. The figure shown below shows a cellular manufacturing layout. From the figure we can see that the materials can be transferred within the cells in many different forms. In the cells 1 and 2, the materials are transferred through same machines in a product focused manner. But in cells 3 and 4 different routes are used for transferring the materials due to differences between the designs of two parts.

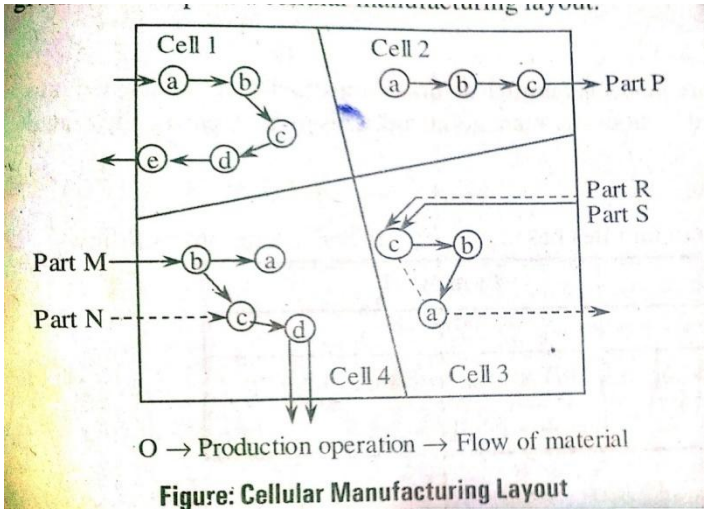


Figure: Cellular Manufacturing Layout

From the figure we can see that the materials can be transferred within the cells in many different forms. In the cells 1 and 2, the materials are transferred through same machines in a product focused manner. But in cells 3 and 4 different routes are used for transferring the materials due to differences between the design of two parts

2.21 SUITABILITY OF GROUP TECHNOLOGY (CELLULAR) LAYOUT:

The following points help us to know the suitability of cellular layout.

- Group Technology layout or cellular layout helps in producing products having different parts
- This layout can be applied in the work centers having easily movable machine tools.
- This layout can be used when the production of a product is independent of its capacity

2.22 OBJECTIVES OF GROUP TECHNOLOGY (CELLULAR) LAYOUT ?

The objectives of Group Technology layout are as follows.

- To increase the rate of production.
- Improves operator's experience, due to repletion of operations.
- Reduces material handling and work in process inventory
- To improve human relations as a group (cell) consists of few operators, which form as small unit team.
- Reduces product cost there by it makes economical.

2.23 ADVANTAGES OF (GROUP TECHNOLOGY) CELLULAR MANUFACTURING LAYOUT.

The advantages of (group technology) cellular manufacturing layout is as follows.

i. Increases reliability of components.,
ii. Increases effective machine operation.
iii. Increases productivity.
iv. High costing accuracy.
v. Increased customer service.
vi. Increased order potential.
vii. Reduced planning effort.
viii. Reduced paper work.
ix. Requires low setting time.
x. Low machine down time.
xi. Low work in progress.
xii. Low work movement.
xiii. Reduced over all production time.
xiv. reduced over all cost

2.24 DIS ADVANTAGES OF CELLULAR MANUFACTURING LAYOUT.

i. It involves less manufacturing flexibility.
ii. Increases the machine down time as machines are grouped as cells which may not be functional throughout the production process.
iii. This group technology layout may not be feasible for all situations.
iv. If the product mix is completely dissimilar, then we may not have meaningful information.

2.25 STEPS INVOLVED IN GROUP TECHNOLOGY (CELLULAR) LAYOUT

The steps involved in Group Technology Layout process are as follows**.**

Step-1. Grouping of parts : The parts are grouped into families depending upon the operations to be performed,

Step-2. Path allocation: The flow path will be allocated depending upon the part families, Product type and sequential order of eperations..

Step-3. Processing of Parts: the parts are processed into respective cells.

2.26 THE METHODS EMPLOYED FOR DEVELOPMENT OF GROUP TECHNOLOGY LAYOUT :

The methods employed for development of group technology layout are broadly classified into two types, they are

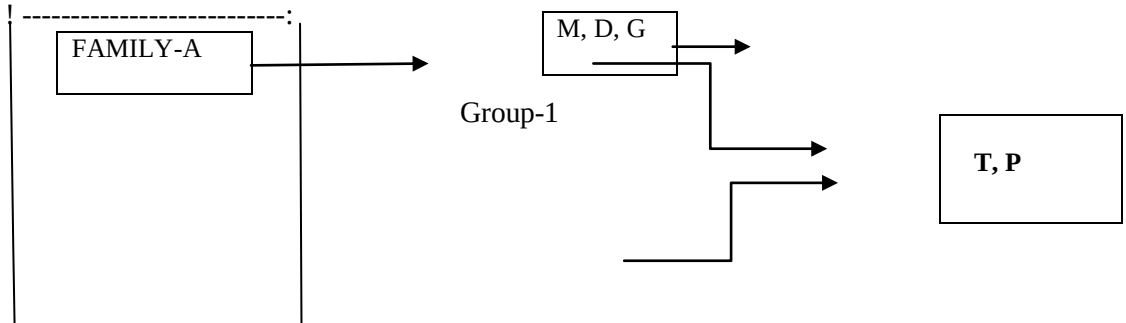
i) Empirical Methods ii) Analytical Methods

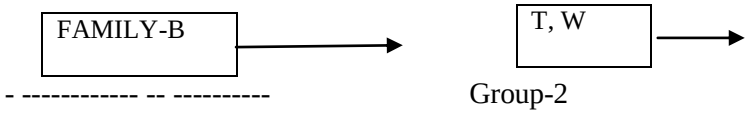
i) Empirical Methods: In this method, the job/components/parts to be processed are made as families and machines/ facilities are divided into groups. This method is used for simple cases and can be performed without any managerial aid. This method can be illustrated in detail by considering an example.

Example: Manufacturing of 80 parts I a plant. The parts are made into families bade on their process operations as follows.

parameters	Family-A	Family-B
mber of parts		
erations be carried out	lling, drilling, grinding & finishing	rning, welding, finishing and painting

It can be observed that the Machines/Facilities can be made into groups as follows.
Group-1: Milling (M), Drilling (D), Grinding (G)
Group-2: Turning (T), Welding (W)
Group-3: Finishing F), Painting (P)
Therefore
, by trial and hit method, layout can be developed as shown in figure below.





The above figure shows an optimal group technology layout for manufacturing of 80 parts

Example:

"BRISCH" is a coding / classification system and consists of 9-digits. Every individual digit represents a specific parameter as shown below.

Digit	Representation
I	Material
II	Shape
III	Size-dimension
iV	Priority of operation
V - IX	Path of operations in ascending order

II. Analytical Methods:

This method is carried out in two steps.

a. Coding/ classification
b. Production flow analysis

a) Coding/classification**: A** code number is provided to each part depending upon its type and operation. Codes will be alphabets or variables to describe the parts. This system can be specific to type (un-standard) or standard type. Computerized/EDP coding/ classification system is usually employed in many industries.

Example:

"BRISCH" is a coding / classification system and consists of 9-digits. Every individual digit represents a specific parameter as shown below.

Digit	Representation
I	Material
II	Shape
III	Size-dimension
IV	Priority of operation
V - IX	Path of operations in ascending order

B) PRODUCTION FLOW ANALYSIS:

In production flow analysis, the flow path of parts will be analyzed. The sequential steps to obtain an optimum path are as follows.

I. Identification of initial operation for all parts.
II. Grouping of machines / facilities according to first operation.
III. Analyzing of second operation for all parts.
IV. Grouping of machines / facilities according to second operation.
V. The above steps are repeated to enhance the complete job work through every machine / facility.
VI. In this process no backtracking is allowed throughout the process.

Example: Manufacturing of parts through various operations such as Milling (M), Drilling (D), Turning (T) and shaping (S).

From the above steps, after identification of all parts, the machines/facilities are grouped as MDMS for first operation, MDMD for second operation and MDMT for third operation respectively. Diagrammatically can be shown as

1 **M**	4 **S**
2 **D**	3 **M**

1 **M**	4 **D**
2 **D**	3 **M**

1 **M**	4 **D**
2 **D**	3 **M**

I- Operation II- operation III- operation

1 **M**	4 **T**
2 **D**	2 **D**
1 M	3 S

Fig: Re-grouped operations

Since, no backtracking is allowed , for identical operations, an additional centers to be are provided. Thus to avoid backtracking the above operation groups can be re-grouped as below

If echmachine is code as given below.
Ie M = 1, D=2, S= 3, and T=4, then re-grouping is coded as

1	**2**	**1**	**3**	**2**	**4**

Therefore , in this procedure the optimum group technology layout is developed by analytical method.

2.27 Fixed Position / Stationary Layout: In this type of layout, material remains at a fixed place and the complete job is done at a fixed station with materials.

-It involves the movement of men and machines to the product which remains stationary for the necessary operations. In this layout, major component remains in a fixed location and tools machinery and men as well as other pieces of material are brought to this location.

The movement of men and machines to the product is advisable because trhe cost of moving them would be less than the cost of moving the product which is very bulky.,

This type of layout is followed in the manufacture of bulky and heavy products such as

Hydraulic turbines, ship building, Locomotive Industry. Construction of building requires fixed location layout because men, cement, sand, bricks, steel, wood and others are taken to the site of construction.

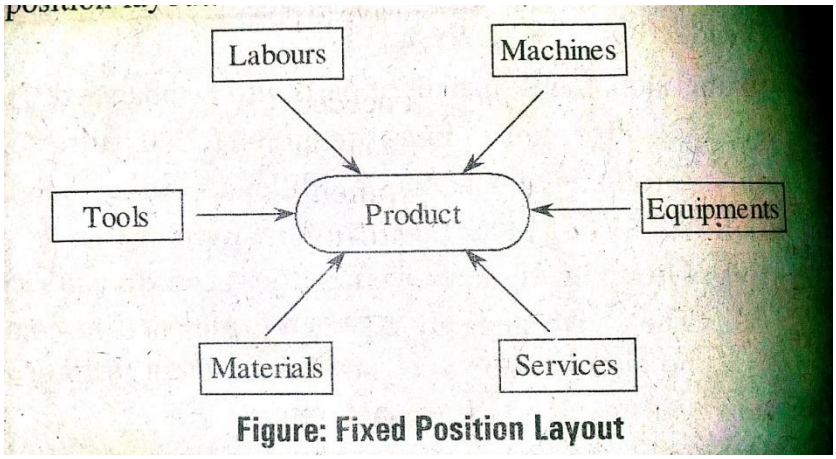


Figure: Fixed Position Layout

2.28 ADVANTAGES OF FIXED POSITION LAYOUT:

i. capital investment is minimum

ii. continuity of operation is ensured.
iii. Less total production cost.
iv. Less material movement.

2.29 DISADVANTAGES OF FIXED POSITION LAYOUT:

i. machine and tools etc. take more time to reach at the work place.
ii. highly skilled workers are required.
iii. complicated jigs and fixtures may be required in fixing jobs and tools **etc.**

2.30 ADVANTAGES OF CELLULAR MANUFACTURING LAYOUT.

i. Increases reliability of components.,
ii. Increases effective machine operation.
iii. Increases productivity.
iv. High costing accuracy.
v. Increased customer service.
vi. Increased order potential.
vii. Reduced planning effort.
viii. Reduced paper work.
ix. Requires low setting time.
x. Low machine down time.
xi. Low work in progress.
xii. Low work movement.
xiii. Reduced over all production time.
xiv. reduced overall cost

2.31 COMPARISION BETWEEN GROUP LAYOUT & FIXED POSITION LAYOUT:

SNO	Group layout	Fixed Position Layout
1	In his layout the machines are grouped into families depending on the sequential order of the job operations	In this layout primary the product is very heavy and is kept in fixed location. The tool, machinery , men an other materials will be transferred to fixd location
2	This layout is also called as cellular layout	This layout is also called as static layout.
3	This layout helps to produce products having different parts.	Find its application in manufacturing heavy products like locomotives, ship, boilers, air crafts and generators.
4	Used when the production of product is independent of its capacity.	When the manufacturing quantity is few pieces of heavy in size
5	Cost of handling material is very less	When the cost of transferring the bulk volume of material is very high.
6	Semi skilled operators are needed to perform work	Highly skilled workers are needed to perform work
7	Easy customer service.	It is very difficult to position the material, object or machines.
8	Reduced planning effort.	More planning effort is required
9	low machine down time.	More machine down time
10	reduced over all cost	Increased over all cost

2.32 ASSUMPTIONS MADE IN QAP. HOW TO EVALUATE AN OPTIMUM SOLUTION.

Assumptions made in Quadratic Assignment method are as follows.

- Net income/revenue from operating plant is equal to the difference of gross revenue and cost of primary input excluding handling cost between plants.
- Flow of material is independent of plant location.

- Transporting cost of unit material is independent of plant and its location.
- Number of departments/ facilities will be equal to number of locations.

Quadratic Assignment Problem (QAP) is a technique of evaluating the prime solution for 'n' number of departments to 'n' number of locations.

The term "Quadratics" means the product of two decision variables and it is a second order function. The term 'assignment' means matching each of the department with specific location. Thus QAP is modeled to facilitate layout for each department with specific location. QAP is a second degree function of variables and constraints are linear functions of variables.

Evaluation of optimum Solution with QAP for plan layout.

For plant layout problem

Notations used in this technique are ;
a_{ij} is net income/ revenue from operating plant 'i' at location 'j'
'f_{ik}' is material flow from plant 'I ' to plant 'k'
'c_{jl}' is transporting cost of unit material fro location 'f' t location 'l'
'n' total number of plants/locations.
'x_{ij}=1 represent plant 'I' is at location 'j'
For this condition, QAP can be formulated as

Max $\sum_{i,j=1}^{n} a_{ij}.X_{ij} - \sum_{i,j,k,l=1}^{n} F_{ik}.c_{ij}.x_{ij}.x_{kl}$ -------- (1)
Subjective constraints

$\sum_{j=1}^{n} X_{ij} = 1$, I =1,2,3,4……n

$\sum_{i=1}^{n} X_{ij} = 1$, j =1,2,3,4……n

$X_{ij} \in \{0, 1\}$, I, j = 1,2,3,4…….n
If 'a_{ij}' is locating and operational cost of plant 'I' at location 'j' then equation (1) becomes

Min $\sum_{i,j=1}^{n} a_{ij}.X_{ij} + \sum_{i,j,k,l=1}^{n} f_{ik}.c_{ij}.x_{ij}.x_{kl}$ -------- (2
Subjective to constrains as same mentioned above

For Facility Layout Problem:

Notations used in this technique are ;
a_{ij} is fixed cost of locating facilities 'i' at location 'j'
'f_{ik}' is material flow between facilities ' i' and 'k'
'c_{jl}' is cost per unit flow of material between locations 'j' t location 'l'
For this condition, Lawler introduced a new decision variable
Ie.,b_{ijkl}= { $f_{ik}.c_{jl} + a_{ij}$ if i =k and j=l
{ $f_{ik}.c_{jl}$if I # k and j #l
Therefore the objective function of QAP is given as

Min $X_{ij} + \sum_{i,j,k,l=1}^{n} b_{ijkl}.x_{ij}.x_{kl}$ -------- (3)
(constraints are similar as mentioned above)

Subjective constraints

$\sum_{j=1}^{n} X_{ij} = 1$, I =1,2,3,4……n

$\sum_{i=1}^{n} X_{ij} = 1$, j =1,2,3,4……n

$X_{ij} \in \{0, 1\}$, I, j = 1,2,3,4…….n

2.34 BRANCH AND BOUND METHOD & STEPS INVOLVED:

Branch and bounding method: This method is used for arriving at an optimal solution to the problem of Quadratic assignment is Branch and Bounding.

Procedure is explained wit example of assigning of four machines in available four locations.

The W_{ij} be the flow of material movement between machines 'I' and 'j' and is shown in below table .

'd_{ij}' be the distance between locations ' i' and 'j' , and is given distance matrix.

Machine \ Location	*1*	*2*	*3*	*4*
1	*0*	*3*	*0*	*1*
2		*0*	*3*	*0*
3			*0*	*2*
4				*0*

Table: Flow matrix

Location \ Location	*1*	*2*	*3*	*4*
1	*0*	*1*	*2*	*6*
2		*0*	*3*	*5*
3			*0*	*4*
4				*0*

Table: distance matrix

Our problem to the machines are assigned to available locations so as to minimize the total cost of material handling.

Solution:

Step-1 : compute the lower-bound to the problem.

The total cost will contain the sum of six elements. Each element being the product of product of one of the element of the flow matrix W and distance matrix.

Arrange the elements of flow matrix in descending order.

The array can be written as A = { 5. 3, 2, 1, 0, 0)

Similarly, the elements of distance matrix are arranged in ascending oder.

The array can written as B = { 1, 2, 3, 4, 5, 6}

The dot product of A and B = 5*1 +3*2 + 2*3 + 1*4 + o*5 +)*6 } = 5+6+6+4= 21

The cost for optimal layout will be 21 or more.

Hence the Lower-bound to the problem = 21

Step-2: perform Branching from the starting node.

Suppose machine-1 is assigned to location-1, for this condition compute the cost of material handling.

The elements of the flow matrix which represent material movement associated with machine-1 are W_{12}, W_{13}, W_{14} (5, 0, 1) . let these be is designated by set P_1 = (5, 0.1)

Distances from m/c -1 to other available locations are d_{12}, d_{13}, d_{14} (1, 2, 6) .

Let these be designated by set Q_1 =(1, 2, 6)

When m/c -1 is assigned to location-1, the other machines 2, 3, and 4 can be assigned to locations 2,3 and 4.ed with these machines designated as set R = { W_{23}, W_{24} W_{34} } = { 3, 0, 2 }

The distance associated with locations 2, 3 and 4 designated as set S = { d_{23}, d_{24}, d_{34} } = { 3,5, 4}

The cost of the layout will consists of six elements with following steps.

I. Crete vectors by arranging set P_1 in descending order and set Q_1 in ascending order find their dot product . call this C_1= P_1 . Q_1 = (5, 1, 0) . (1, 2, 6) = 5*1 + 1*2 + 0*6) = 8

II. Cerate vectors by arranging set R in descending order and set S in ascending order .find their dot product. Call this as C_2

III. Find the lower bound by adding C_1 and C_2 , LB = C_1 + C_2

For present case , the lower-bound =LB= { P1 descending . Q1 ascending + R descending . S in ass }

= { (5, 1, 0). (1,2,6) + (3, 2, 0). (3,4, 5) } =

= { 5 + 2 + 0 } + { 9 + 8 + 0} = 7 + 17 = 24

Similarly , the lower-bound , when facility-1 is assigned to locaction-2, location-3 and location-4 can be evaluated and results are shown in following table.

Table: Lower-bounds when facility-1 is assigned to locations 1,2,3 and 4

Facility-1 is assigned to	*Lower-bound*
Location-1	*24*
Location-2	*22 * (lowest bound)*
Location-3	*26*
Location-4	*32*

Facitiy-1 can be assigned in four feasible ways. Therefore , the options can be pictorially represents as in figure: 9.4

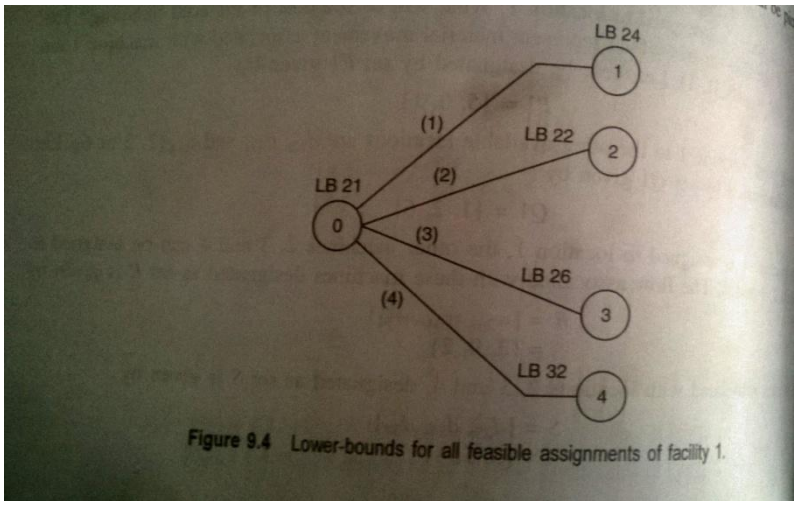


Figure 9.4 Lower-bounds for all feasible assignments of facility 1.

UNIT – IIIA

INTRODUCTION TO MATERIAL HANDLING SYSTEMS

3.0 MATERIAL HANDLING- definition:

Definition: Material handling is defined as movement of material of any form (raw material, finished, packaged, solid, liquid, gas,, light and heavy from one location to another location, either in a restricted path by manual or mechanical aids. The movement may be either horizontal, vertical or may be combination of both.

.Material handling involves all those activities that are responsible for efficient movement of goods either with in a plant or a warehouse or between a plant and a transportation agency.

3.1 IMPORTANCE OF MATERIAL HANDLING:

Importance of material handling can be studied under following aspects. They are

i) **Movement**: It is associated with the transfer of goods into and out of storage facilities or within these facilities. Efficiency of material handling can be achieved by efficient transfer of goods to, from and within the storage facility.

ii) **Time:** Aspect of time can be studied from production and customer's perspectives. In case of production, it refers to the time required for bringing the raw materials to the production site. Efficiency is said to have been achieved, if it has to encounter problems of work stoppage, higher inventories and increased space of storage.

Similarly, from the customer's point of view, it refers to the time required by the firm for the fulfilment of their orders. Even, reduced shipment time/cycle time is said to be efficient.

ii) **Quantity**: Quantity refers to the amount of raw materials/finished goods transferred from/to an organization. It accurate estimation results in delivering right product to the right customer at the right time in right quantity.

iv) **Space:** Space refers to the warehouse/plant capacity used by the material handling equipment. Such space will be fixed. However, efficiency of operations can be achieved by efficiently utilizing this space.

The logistics manager is held responsible for all these material handling tasks which involves. Coordination between the different individuals of an organization. Hence, while designing a materials handling system, every firm must consider both its long-term plants and its available resources.

3.2 OBJECTIVES OF MATERIAL HANDLING:

The following are the objectives of material handling.

i. **Increased usage capacity:** It is mainly focused to increase the effective usage capacity of a warehouse. A both horizontal and vertical capacity of a warehouse needs to be utilized in an efficient manner, such that the firm must achieve both economies of scale and scope.

ii. **To minimize Aisle Space:** 'Aisle space' refers to a passage present between the rows of shelves. If materials are handled with care, this can be reduced to a great extent so as to accommodate more quantity of materials than they have been used to do it before.

iii. **Reduces Handling Frequency**: In case of logistics management, materials initially move from the source to the warehouse, then they can be transferred to order selection areas where they can be picked up and made into orders and then finally, to their shipment areas where they are ready for final consumption by the customers. During all these stages, several unnecessary movements of goods can be practiced by a firm which has to be avoided in order to enhance the operational efficiency of ware- house. Thus, firms should design material handling system

in such s way which helps them in minimizing the movement of goods to, within or from a warehouse.

iv. **Develops Effective Working Conditions:**

It focuses mainly on the development of secure and safe working environment where employees develop s sense of safety while working in an organization.

v. **Automated Movement**: Automated material handling system reduces the Burdon of manual labor by combining them with automated systems, because there are certain areas where operations cannot be performed without making use manual labors. The best example might be the activities associated with the order picking area. Hence, an organization needs to develop an environment in such a way that it would stimulate people to perform the job efficiently.

Vi **Improved Logistics Service:** It helps in improving the efficiency of logistics system by effectively fulfilling the customer requirements. It is responsible for the conveyance of goods to customers on time and in proper quantities. Due to efficient movement of goods into warehouse or properly locating the stock or by accurately filling the orders and also by properly preparing orders for shipment to customers, material handling forms a crucial component of an outbound logistics. This objective is greatly emphasized by the logistics manager which makes him to strive hard to ensure that the customer's orders and the production requirements are responded and met quickly and efficiently.

Vii **Eliminating short-distance warehouse movements**: This objective is mainly concerned with reducing the short-distance warehouse movement by locating warehouses near to the production plant. However, it would be very much difficult for the firms to eliminate the day-to-day routine movement of goods but still it can eliminate such works to the maximum possible extent.

Viii **Minimizes Cost:** By incorporating flexible material handling within the customer service programmes, it improves integrity among various departmental needs. Effective materials handling increases productivity which in turn reduces the cost of operations. Even this can also be reduced by efficiently utilizing the space requirements.

3.3 FUNCTIONS OF MATERIAL HANDLING

The main functions of material handling are listed below

i. It selects the type of machine, equipment and plant layout, so that the material handling requirements can be minimized.

ii. It includes the choice of convenient, effective and protected material handling equipment.

iii. It helps in reducing the material handling cost by considering the following..

- Minimum movement of semi finished products during the manufacturing.
- Planning of movement of number of parts under one unit
- Minimizing the travelling distance between the departments.
- By increasing operational speed of handling through mechanization.
- Removing backtracking and duplicate handling.
- use of gravity for material handling.

3.4 JOBS OF MATERIAL HANDLING

Material handling performs the following operations.

i. It receives the incoming raw material and delivers (ie shipping) the outgoing products.
ii. It transports the materials to its processing area by handling in work place or in line or in interdepartmental or in intercompany .
iii. It carries and stores the products at a suitable place.
iv. In addition to the above operations, it can help in transport arrangement, products delivery etc., depending upon the requirement

3.5 CHARACTERISTICS /FEATURES OF MATERIAL HANDLING EQUIPMENT:

Equipments of material handling comprises of some special characteristics or features which are listed corresponding to the following parameters as follows,

A) Materials

(I) Bulk (in huge quantity) (ii) Packaged

B) Movement of materials

(I) In horizontal direction (ii) In vertical direction

(iii) Both horizontal & vertical direction

C) Supervision required for equipment.

(I) More (ii) Less (iii) Automatic or semi-automatic type

D) Path to be followed for materials

(I) Variable (ii) Flexible (iii) Fixed area

E) Mode of speed

(I) Variable (ii) Fixed (iii) Fixed or variable

F) Source of power for the operation of an equipment.

(I) Electric Power (ii) Power from. I.C engine

(iii) Manual power (iv) Gravity power

3.6 MERITS/ADVANTAGES OF MATERIAL HANDLING SYSTEMS

- It reduces the time required for handling the materials
- Reduction in material handling & indirect labour cost.
- Improvement on productivity
- Better usage of floor space & facility
- Least fatigue to the worker
- Improved work environment
- Reduction in bottle necks

- Greater flexibility
- Improvement in safety & reduction in accidents.
- Improved material flow (Less back tracking
- It promotes a protected and clean material handling without any difficulty.
- It eliminates the idle time of workers and machines.
- Increases the flow rate of materials from one workstation to another..
- Material handling is a secured process.
- Compact and better stocking of materials in good location available in plant.

UNIT- IIIB

MATERIAL HANDLING PRINCIPLES, CLASSIFICATION OF MATERIAL HANDLING EQUIPMENTS, RELATIONSHIP OF MATERIAL HANDLING TO PLANT LAYOUT

3.7 PRINCIPLES OF MATERIAL HANDLING:

The design analysis and operations are the areas of application of material handling system. Several principles of material handling are employed for better utilization, safer operating conditions, lower costs and better performance of material handling

i. **Planning principle:** The material handling systems should have well planned methods which consisted of objectives of performance, needs and characteristics of the product.
ii. **Standardization Principle**: To achieve the objectives of performance of handling system, standardize the material handling method, equipment, control without influencing flexibility, modularity and the amount of material moving through the system.
iii. **Work principle:** Minimize the material handling work without affecting the level of service required at the operations and productivity.
iv. **Ergonomic principle:** To ensure safe and effective operations for the human worker, the capabilities and limitations should be adapted, designed at the time of material handling task and equipment.
v. **Unit load principle:** Unit load should be sized and arranged in a manner, which completes the objectives of material flow and inventory at each stage of supply chain.
vi. **Space utilization principle:** The overall space available should be used efficiently and effectively.
vii. **System principle:** For the formulation of coordinated and operational system, the material movement and storage activities should be fully integrated.
viii. **Automation principle:** The material handling system should be automated or mechanized to improve operational efficiency, reduce manual labour and operating cost.
ix. **Environmental principle**: The designing and selection of equipment and material handling system depends on the criteria of environmental Impact and energy consumption.
x. **Life cycle cost principle**: The system should have thorough economic analysis for entire life cycle of the material handling system and equipments.

3.8 VARIOUS TYPES OF MATERIAL HANDLING EQUIPMENTS

The material handling equipments are broadly classified into various types based on four categories.

A) Design features
B) Nature and type of work
C) Working area
D) Movement or motion of materials

A. Design features: According to design they are classified as

A. 1. Hoisting equipment

A. 2 conveying equipment

A. 3 surface and overhead equipment.

B. Nature and type of work:

Equipments used for the movement and storage of materials at site are classified as

B. 1 Transporting equipments such as industrial trucks, cranes, conveyors.

B. 2 Positioning equipments such as hoists, lifts, parts feeder, levelers etc.

B. 3 Unit load formation equipments such as pallets, bags, crates, tote pans, cartoons etc.

B. 4 Storage equipments such as storage carousel, sliding racks, pallet racks, mezzanine etc.

B. 5 Identification and control equipments such as magnetic stripe, bar codes, radio frequency tag, machine vision etc.

C. Working area:

In this category, equipments are classified as

1. Unrestricted Area: equipments such as trucks, tractors, carts etc.., which are restricted to move in any direction.

2 . Restricted Area: Equipments such as gantry cranes, overhead travelling cranes and stacker cranes, which are confined to working area.

3. Line Restricted: Equipments such as lifts and elevators, conveyors, AGV's etc .. Which follows a continuous specified path for transportation of materials?

4. Position Restricted: Equipments such as job cranes and other industrial robots which are fixed units and works in specified areas from its position.

5 Auxiliary Equipments: Equipments used to improve the effectiveness of handling such as unit load carriers, dispatch Equipments, assembling and securing Equipments.

D. MOVEMENT OR MOTION OF MATERIALS:

According to path of move the equipments are classified as,

1. Vertical motion (for lifting and lowering)
2. Horizontal motion (for transportation)
3. combined horizontal and vertical motion

3.9 CONVEYORS:

i. **Roller conveyors**: Roller conveyors contain a series of rollers or tubes along their path. Position of rollers are perpendicular to the direction of motion of conveyor. The rollers are placed in a fixed frame which elevates the conveyor path above the floor level from several inches to several feets.

For this purpose tote pans or pallets or cartons are employed. When the rollers rotate the unit loads carried by flat pallets or tote pans moves forward.

Roller conveyors are two types

- **Power Roller conveyors:** These are driven by means of chain or belts.
- **Non-powered Roller Conveyors:** These are driven by gravity. Hence the path has sufficient downward slope to overcome the rolling friction.

To deliver the loads from storage compartment in between manufacturing operations, roller conveyors are employed. It can also be used in sorting/merging operations.

ii. **Skate wheel conveyors:** Skate. Sheet conveyors contain skate wheels rotating on shafts which are connected to a frame to roll tote pans, pallets and other containers located along their path. This the design and operation of these conveyors is same as that of roller conveyors with a difference that these conveyors use skate wheels in place of services of rollers.

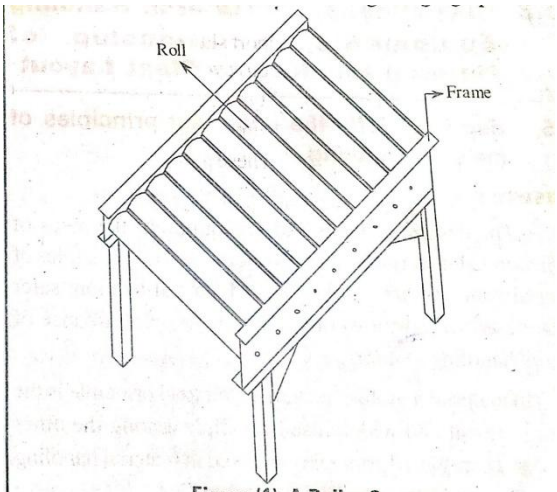


Figure (1): A Roller Conveyor

The weight of skate wheel conveyors is very low compared to the roller conveyors. Therefore the loads should be light in weight as the contacts between the loads and conveyors are highly concentrated.

iii. BELT CONVEYORS: Belt conveyors use a belt made of rubber, which is a reinforced elastomer. The operation of belt conveyors is carried out in a continuous loop. Half length of belt is used to carry and deliver the items or materials where as other half length id is for return path.

A frame containing support sliders or rollers along its forward loop is used to support the conveyor belt. A drive roller is provided at one end of the conveyor to power the belt.

Belt Conyers are two types

- Flat belt: These are used for individual parts or pallets
- Troughed Belts: These are used for Bulk materials like gravel, coal, grain

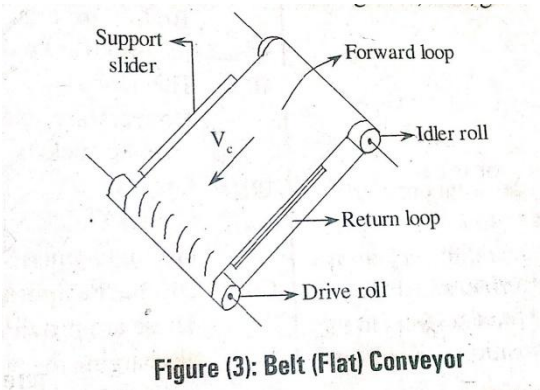


Figure (3): Belt (Flat) Conveyor

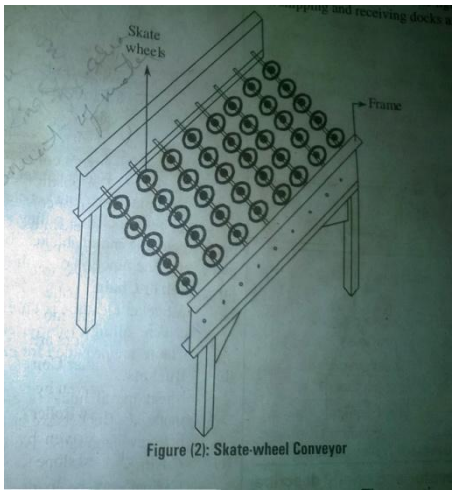


Figure (2): Skate-wheel Conveyor

USES OF SKATE WHEEL CONVEYORS:

skate wheel conveyors can be used in the same application of roller conveyors..

..the light weight feature of these conveyors finds its use in loading and unloading of truck trailers at shipping and receiving docks at factories.

iv. Power and Free Overhead Trolley Conveyor: This type of conveyor equipment consists of a wheeled carriage fixed with trolleys engaged on the tracks or beam. The track includes upper and lower track. The lower track carries from trolleys spaced along a fixed track. While the upper track carries continuously moving endless chain. When the driving chain is connected to the trolley from upper track, the load travels from one path to another path. When the driving chain is disconnected then the trolley becomes idle. This conveyor is applicable in factories to move parts and assemblies in the production system. This conveyor is used for storage and delivery of materials or parts

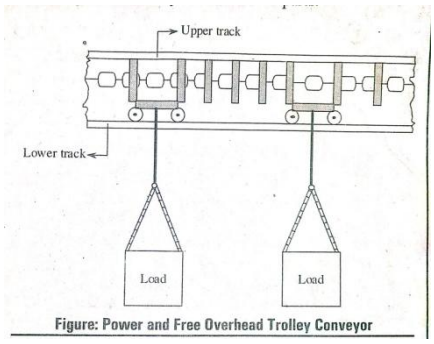


Figure: Power and Free Overhead Trolley Conveyor

iv. ELEVATOR: Elevator is a group of Equipments used in material handling to transfer the bulk quantity of materials from lower heights to upper heights. There are four types of elevators and are as follows.

- Bucket elevators
- Fright elevators
- hoist elevators
- lifts

Bucket elevators: It is a simple, reliable and powered equipment used for lifting bulk materials from lower heights to upper heights. It is driven by chain or belt drives on which, metallic buckets are attached. The buckets move in unidirectional and lift the materials from lower surface by scooping and deliver to the upper surface by centrifugal action.

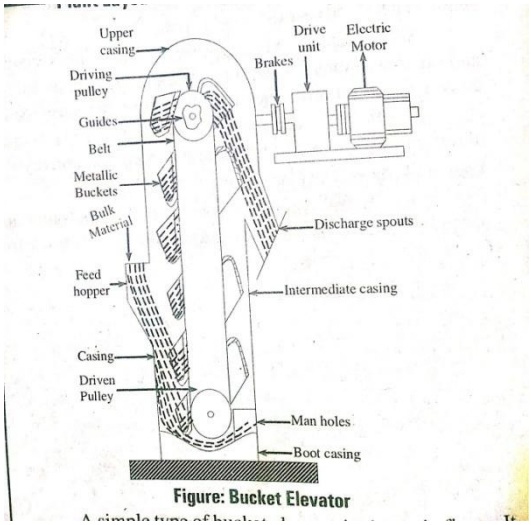


Figure: Bucket Elevator

A simple bucket elevator is as shown in above figure. It consists of belts or chains, pulley, sprockets, casings, metallic buckets, electric motor, brakes, hoppers, spouts, manholes, guides etc. The function of each equipment is as follows.

- **Belt chain:** A bucket elevator has endless chain driven or belt driven pulling system used to pull the buckets. Belts/chains are provided for carrying the buckets.
- **Buckets**: Sheet metal buckets are used for handling bulk materials. Buckets are fastened to chain/belt by means of screw and nuts, rivets etc.
- **Casing:** Casings are provided for covering the entire elevator. There are three casings provided for bucket elevator ie., upper casing, lower casing and intermediate casing.
- **Drive unit:** Drive units are provided for driving the pulleys using belt drives. These units are situated at the upper end casings and are driven using the electric motors.
- **Brakes:** Brakes are attached to pulley/shaft for preventing the backward motion of the elevator when it is not in use.
- **Hoppers:** Hoppers are used for filling the bulk material into metal buckets.
- **Guides:** Guides/Guide sprockets are provided for preventing misalignment of belts and chain in bucket elevators.
- **Discharge Spouts**: These are provided at the upper portion of casing for discharging the bulk material from the metallic buckets.
- **Manholes:** These are located at the lower casing for checking the operation of an elevator.

Hence, the bucket elevators are used for delivering the bulk materials such as coke, coal, carbon, ash, aluminum. Ore, pulverized chalk etc., from lower heights to upper height in vertical or inclined direction.

3.10 CLASSIFICATION OF BUCKET ELEVATORS

Based on the method of unloading (discharging) and bucket spacing, bucket elevators are categorized into three types

i. TYPE-I or centrifugal discharge elevators
ii. TYPE-II or Continuous discharge elevators
iii. TYPE-III or positive discharge elevators1.TYPE-I or centrifugal discharge elevators

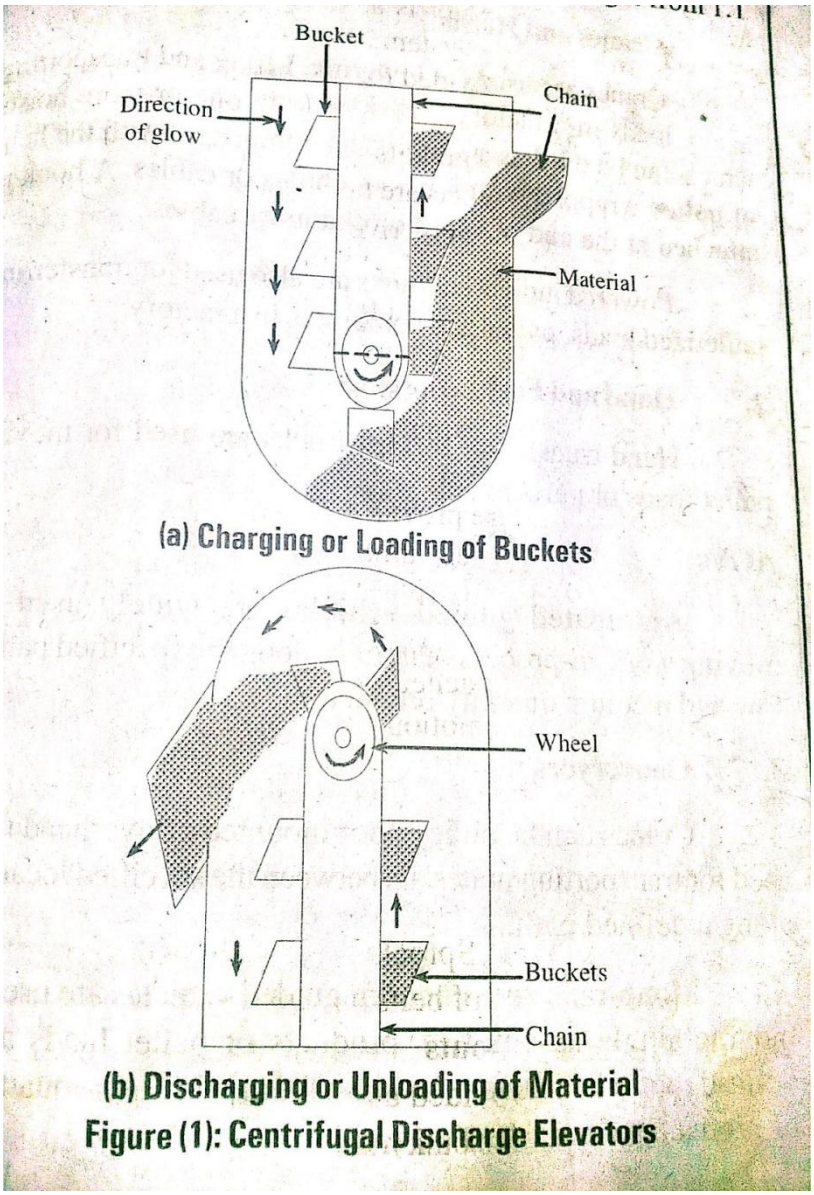


Figure (1): Centrifugal Discharge Elevators

ii) TYPE-II or continuous Discharge Elevator:

Type-II elevators are modified form of type-I. The Buckets are designed in v-shop or closely positioned without any gap between them. The V type buckets are loaded by direct filling and unloading is directly by gravity. The flanged end of V-type buckets act as chute and delivers material slowly into discharge spout, when buckets passes over head wheel. This type of loading and unloading unsuitable for fragile materials. Both belt and chain drives are employed to drive the pulleys. These elevators may be inclined or vertical type. For inclined type , special supports have to be provided for belt or chain for return run and to allow the return run sag a wider casing us employed. The speed of this elevator is kept relatively at low range. This type of elevators are used to handle by centrifugal discharge elevator

iii). TYPE-III or positive Discharge Elevators

The construction of type-III elevator is similar to type -I elevator, except that buckets are side mounted on two strands of chain. The buckets are equally spaced on chain to avoid interference. To inver the buckets for complete unloading, buckets are provided with a pair of Snub Sprockets incorporated under head Sprockets. The loading is carried out by scooping or digging action of bucket and unloading is through centrifugal action. The speed of this elevator ranges from o.6 to o.67 rpm. An inclined type-III elevator specifically suitable for perfect gravity discharge applications. Light weight materials, fluffy sluggish and slightly sticky materials are more suitable for this elevator.

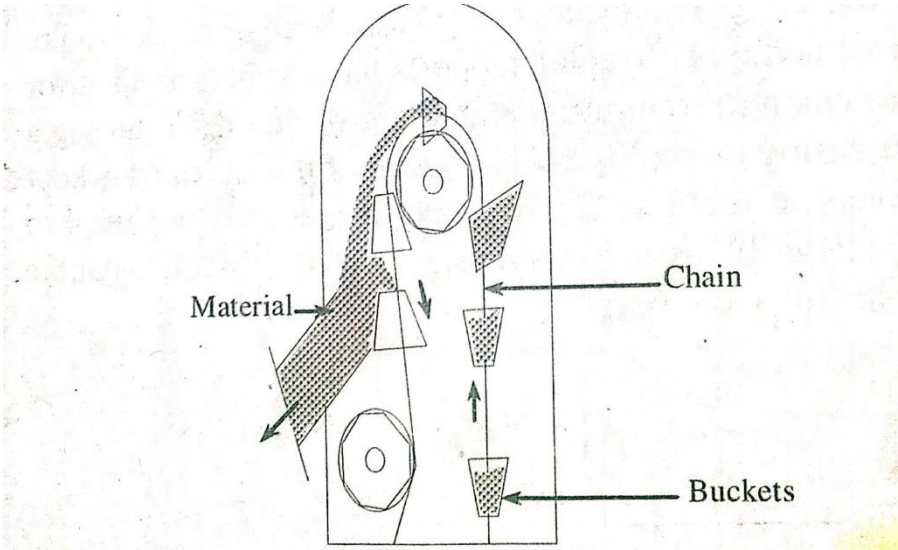


Figure (4) : Discharging of Type-III Elevator

3.11. HOW MATERIAL HANDLING IS RELATED TO PLANT LAYOUT. Or RELATIONSHIP BETWEEN MATERIALS HANDLING AND PLANT LAYOUT.

It has been observed that plant layout is closely interrelated to material handling system, as good layout provides the minimum rate of material handling and eliminate re-handling.

The material handling parameters to be considered in designing plant layout are

i. **Excess movement of materials**: Can cause damage to materials and effects the valuable time of workers in shifting the materials. Hence a well planned plant layout reduces the material handling

ii. **Time Utilization**: Saving the worker's productive time by providing a good plant layout, enhances an effective production. Plant layout should have minimum workman travel and clearly identified well-named functional areas, distinct areas for raw materials, tools, work-in-process, inspection of finished goods, et .

iii. **Economical use of Space:** An important perception in plant layout is space. All the machines and equipments have to be arranged in sequential and well-planned manner such that, no empty space should be wasted. There should be a possibility of optimum choice of expansion in future.

iv. **Use of Miscellaneous Tools:** The effective utilization of bins, trolleys, racks, trays, conventional packing techniques, conveyors, chutes, inclined planes and gravity feed-bins reduce material backtracking and unnecessary movement of workers. Thus effectiveness in manufacturing can be obtained.

Therefore, a good plant layout provides an effective material handling. System which ensures minimum material handling.

3.12 DIFFERENT TYPES MATERIAL HANDLING EQUIPMENT ASSOCIATED WITH DIFFERENT PLANT LAYOUTS

The different types of material handling equipment associated with different plant layouts are

i. Cranes, hoists,

Industrial truck } →Fixed position layout

ii. Hand trucks, forklift,

trucks. Automated trucks → Process Layout

AGV's.

iii. Conveyors. → Product layout

i.**Cranes and Hoists:**

Cranes are used lowering, lifting and transporting heavy loads in a factory. Provided with one or more hoists which can be used as a load lifting component with the help of pulley wrapped with ropes or chains or cables. A hook is attached at the end of rope or chain or cables.

Powered industrial trucks are also used for transferring palletized loads, palletized container in a factory.

ii. Hand and Forklift Trucks:

Hand trucks and forklift trucks are used for moving pallet loads or parts in a factory.

AGV's: Automated guided vehicles are widely used for moving work-in-process materials along the specified path in low and medium quantity production.

iii) Conveyors: Mono-rails and other rail guided vehicles are used for moving single assemblies, products or pallet loads along defined routes in a factory and also for moving large quantities of products over a fixed routes.

UNIT – IV

BASIC MATERIAL HANDLING SYSTEMS:

4.1CLASSIFICATION OF BASIC MATERIAL HANDLING SYSTEMS:

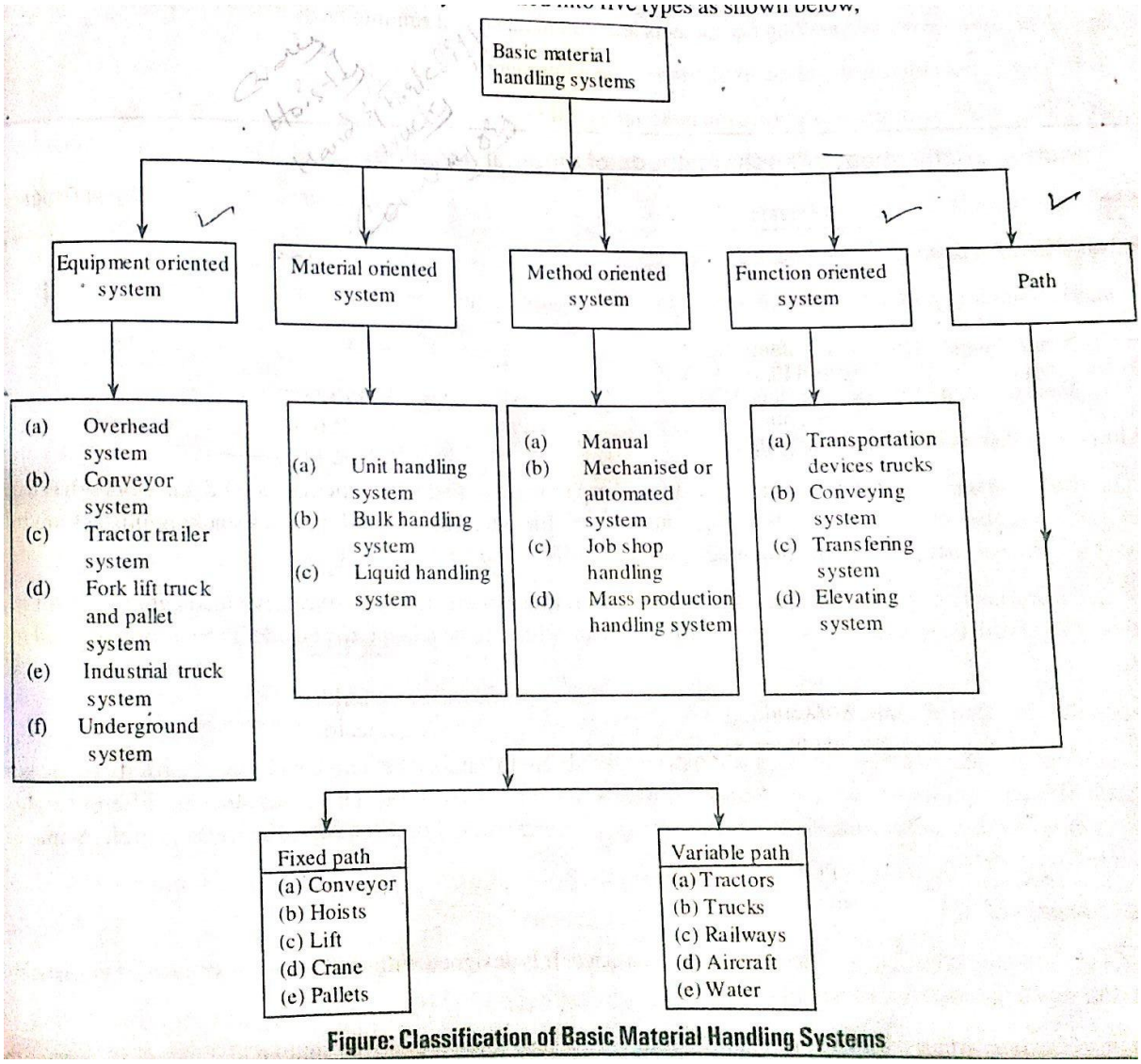


Figure: Classification of Basic Material Handling Systems

Basic material handling systems are mainly classified into five types as shown below

1. Equipment oriented system:

1.1 over head system
1.2 conveyor system
1.3 tractor trailer system
1.4 fork lift truck and pallet system.
1.5 industrial truck system
1.6 Under ground system.

2.0 Material oriented system:

2.1 unit material handling system.
2.2 Bulk handling system.
2.3 Liquid handling system.

3.0 Method oriented system:

3.1 Manual system
3.2 Mechanized or Automated system.
3.3 Job shop handling
3.4 Mass production handling system.

4.0 Function oriented system

4.1 Transportation devices, Trucks
4.2 conveying systems
4.3 Transferring system
4.4 Elevating system.

5.0 Path oriented system

5A: Fixed path oriented system

5a.1: Conveyor
5a.2: Hoists
5a.3: Lift
5a.4: Crane
5a.5: Pallets

5B: Variable path oriented system.

5b.1: Tractors
5b.2: Trucks
5b.3: Railways
5b.4: Aircraft
5b.5: Water

4.2 FACTORS TO BE CONSIDERED WHILE SELECTING MATERIAL HANDLING EQUIPMENT.

The material handling equipment should be selected very precisely so that, it cannot affect the production and operations costs. Thus the factors that are to be considered during selection of material handling equipments are,

i. The plant lay out (product and process layout)
ii. The type of process (either continuous or intermittent flow process)
iii. The sequence of operations to be performed for product.
iv. Type of process (is it batch or JIT process)
v. The plant building construction details
vi. The existing material handling equipments.
vii. The final cost of product.
viii. The physical & chemical properties of the material to be handled.
ix. The flexibility, reliability, speed and efficiency of material handling equipment.
x. The noise of machines and exhaust gases of material handling equipment.
xi. The future costs of handling equipments maintenance & running costs.
xii. The depreciation rate of equipment.
xiii. The safety of employees during the material handling.

4.3 METHOD ORIENTED MATERIAL HANDLING SYSTEMS (different methods of material handling)

Material handling processes are categorized into two groups namely

i. Manual method of material handling
ii. Mechanical method of material handling

i. **Manual method of material handling**: In industries, manual handling of materials is the major part of unskilled labour. In this method, the worker has to lift and move the heavy loads by activities such as lowering, pushing, pulling etc. This method includes stacking/un stacking loads on pallets, stacking shelves,

lifting and lowering loads, moving trolleys and packing stock. when the worker performs these kind of activities due to improper handling or excessive loads, it may result in either physical risk or injury to the worker (s). Therefore, safety measures have to be taken into consideration during manual material handling.

ii. **Mechanical material handling:** This method of material handling arises when the materials are to be handled beyond the physical capacity of the workers. In this method, different equipments are used to move, store, motion control and protect the materials. The different equipments that are most commonly used are cranes, elevators, conveyors, platform trucks, forklift trucks, electric hoists, etc. Some of them are discussed below in detail

- Fork lift trucks (FLT): FLT is self loading wheeled vehicle with counter balance. It is designed with an operator seating arrangement to raise , lower and move the loads as shown in figure.

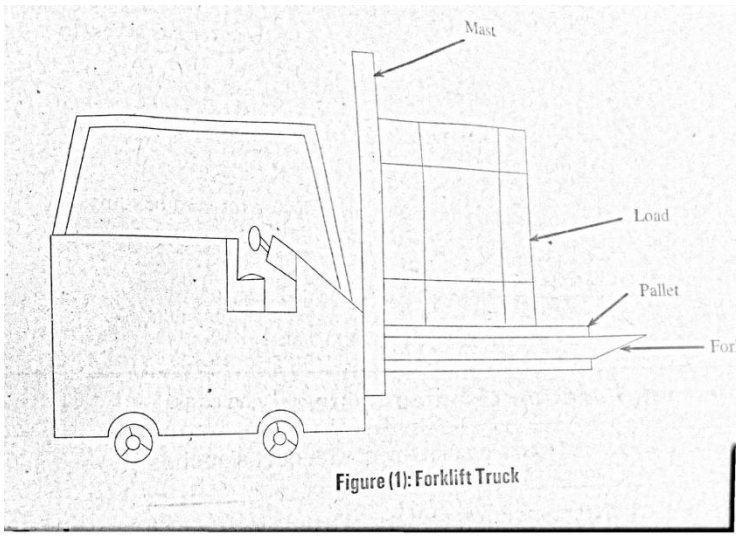


Figure (1): Forklift Truck

It is a power driven truck with two forks at its front end. These forks are moved in up and down directions either by mechanical or hydraulic mechanisms. A pallet is a wooden platform on which loads are placed. The pallet is incorporated with square holes I. Its opposite adjacent k. The forks are inserted into these square holes to carry the load along with the pallet. FLT can carry medium to heavy loads and can raise the load upto the maximum limit . The power driven to FLT is either by diesel/petrol/LPG engines or battery driven motors. These trucks are used for lifting, lowering, stacking/us tacking, loading, unloading of uniform shaped units intermittently.

- **Platform Trucks:** The platform trucks comprise of strongly built metallic platform. It is powered by battery driven motor, diesel/petrol or gas engines.

The fixed platform trucks are non-elevating with higher carrying capacity. The loads are to be transferred are loaded on the platform either manually or by any other equipment. In small capacity truck models, the operator has to stand and control the vehicle.. In large trucks, the operator has a seating arrangement along with a steering mechanism. A typical powered fixed type platform truck is shown in figure below.

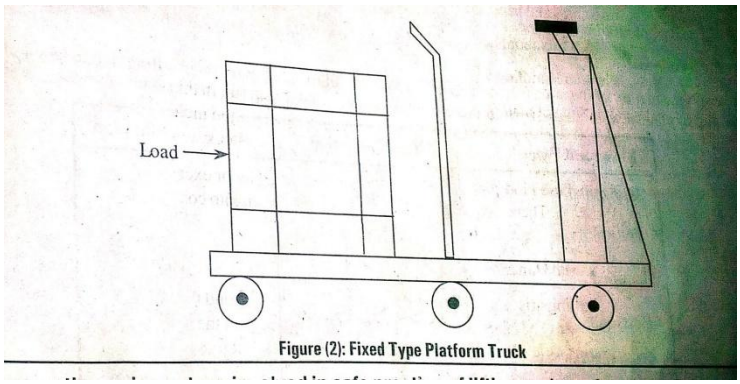


Figure (2): Fixed Type Platform Truck

4.4 FUNCTION ORIENTED MATERIAL HANDLING SYSTEM.

Function oiented system is defined as corresponding function performed by material handling Equipments. This system is classified as follows

i). transportation system or equipment: This type of equipments or systems is used for fixed routes only in horizontal direction. The path followed is either straight or curved. It uses power driven mechanism for its motion. The various types transportation systems are

- **hand truck:** It requires lage amount of man power. These Equipments posses high flexibility, easily portable and are economical
- **Narrow gauge rail road:** These Equipments are used in metal working industry and mining activities.
- ..it possesses less flexibility and are difficult to operate.

- **Industrial tractors and trailers:** These Equipments are the most commonly used horizontal mode transportation system in industries. It possesses high flexibility and are economical
- **walkie trucks:** These are powered trucks which are operated by means of controls that are incorporated on truck handle.
- these are small, light in weight and operate slower than other trucks
- **Skids:** These are combinely used with lift trucks to move the loads from one location to another. skids and pallets are used to raise the load from ground level and provided less effort in conveying the load.
- **Dollies:** They are used for storing the materials. These are moved upon their casters.
- **Combination devices:**
- chutes: This is the simplest equipment which has both horizontal and vertical motion.(that may bea spiral or straight chutes. Gravitational force is utilized to move materials
- Lift trucks: These are combinely used with skids and pallets. It is easy to operate and lift material from floor.
- Crane trucks: This can lift material without using skids and pallets. The crane trucks are rotary and can lift material from any position.
- Fork Lift Trucks: These are powered trucks. The operator can alone lift and carry , load and unload the materials. These are widely used in workshops, stores, for lifting heavy coils, sheet metal, tyres etc.

ii) CONVEYING SYSTEMS or EQUIPMENTS:

material handling Equipments are power driven machines used for moving the materials over vertical, horizontal and inclined paths. These are straight or curved and are continuous in motion. The materials can flow in horizontal and inclined paths with either continuous orreciprscating motion. The various conveying systems are as follows.

- Belt conveyors: These are commonly used for material handling in industries such as mining, construction etc. It is light in weight and these consume less power and are noiseless. These are the continuous material handling equipment and are very costly

- Chain Conveyors: These conveyors are operated by chains in horizontal and inclined directions. It is used for transferring heavy oil barrels and boiler accessories.
- Roller Conveyors: These conveyors are operated using rollers that are supported in frames and are driven by gravitational force. It is used for transporting rectangular boxes or other materials in horizontal and vertical directions.
- Screw conveyors: These are used for transporting the materials which are in the form of powders and pastes. These can be made dust free conveyors if they are enclosed.
- Bucket conveyors: In these types of conveyors buckets are used for transporting the material from lower height to upper heights.
- Elevating conveyors: These elevators are used for transferring the material in vertical directions using buckets. These are used for transporting the dry granular materials like coal, cokes etc.
-

ii) TRANSFERRING SYSTEM OR EQUIPMENT:

In this type of Equipments or systems, the load is lifted and moved in air to an exact desired location within limits (range) of equipment. The motion in this type of equipment is intermittent (discontinuous). The Group of machines used for lifting the load to very high heights and moving the load are known as transferring system Equipments.. The different types of transferring systems are tabulated as follows.

- **Cranes:** These are the material handling Equipments used for lifting or lowering the material or load. The cranes are power driven or operated manually.
- **Jib cranes:** job cranes are stationary cranes, manufactured from a I-sectioned beam. Jib cranes are widely used cranes in manufacturing industries and are economical. Jib cranes can lift load to a maximum limit of 15 tones.

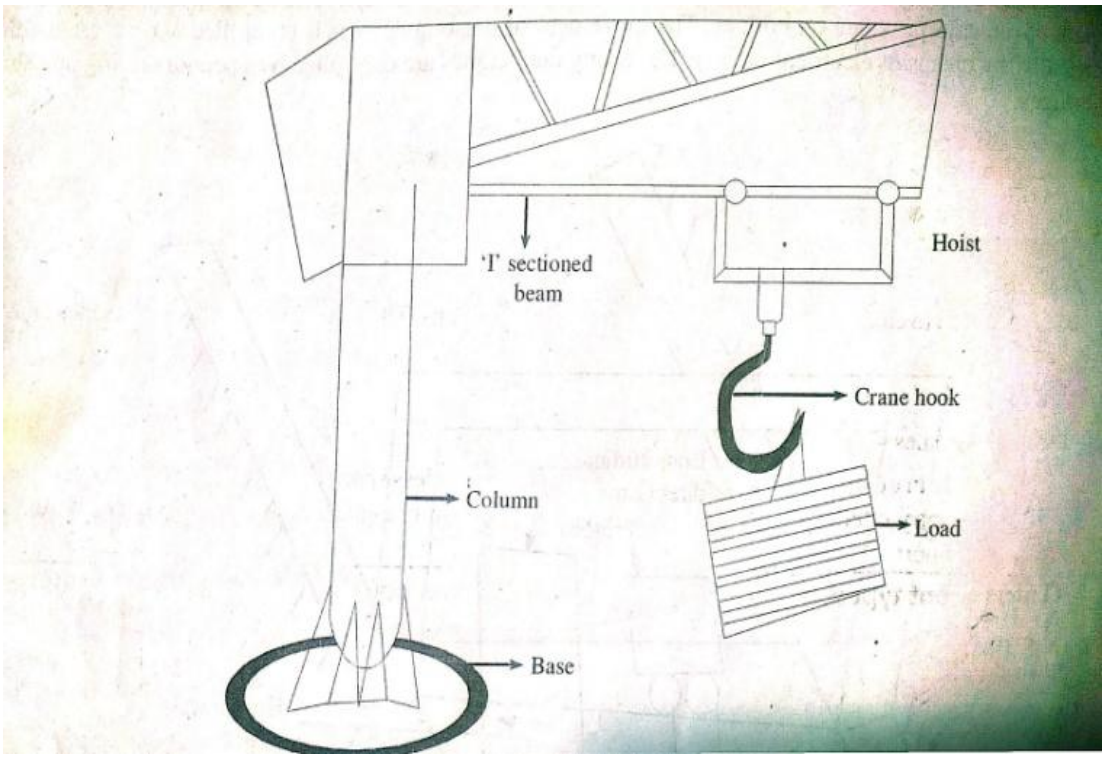


Fig: Jib crane

- **Overhead cranes:** These cranes are mounted on the bridges and the runways are installed on building columns and frames. These are operated by electrical power systems and by skilled operators. It can lift the load ranging from about 1 tons to 1000 tons. These cranes require heavy frame work and are very expensive.

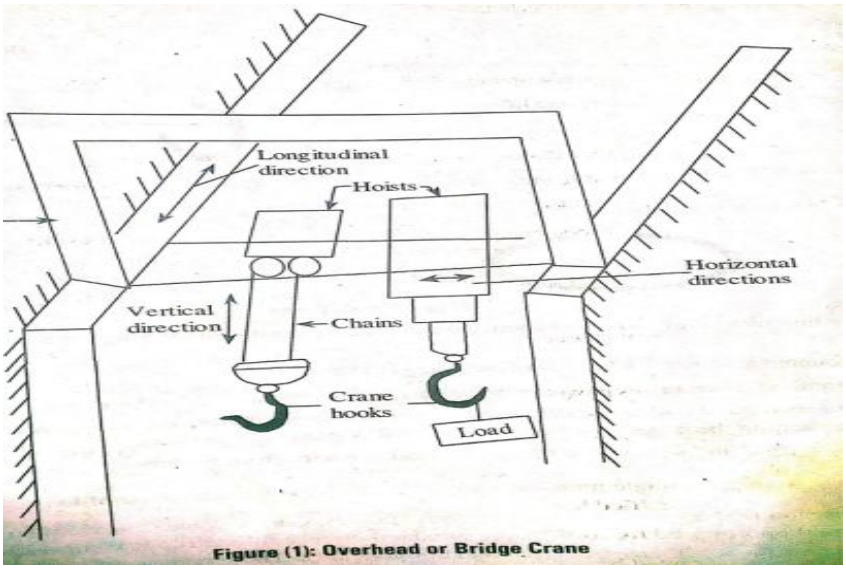


Figure (1): Overhead or Bridge Crane

- **Gantry cranes:** These are similar in operation to bridge cranes, but differ only in arrangement of supports. It is supported by two are more legs with wheels attached to the supports. These cranes are used for both indoor and outdoor industries. They have long span of life and low maintenance cost. It has the capacity to lift the load ranging of about 300 tons.

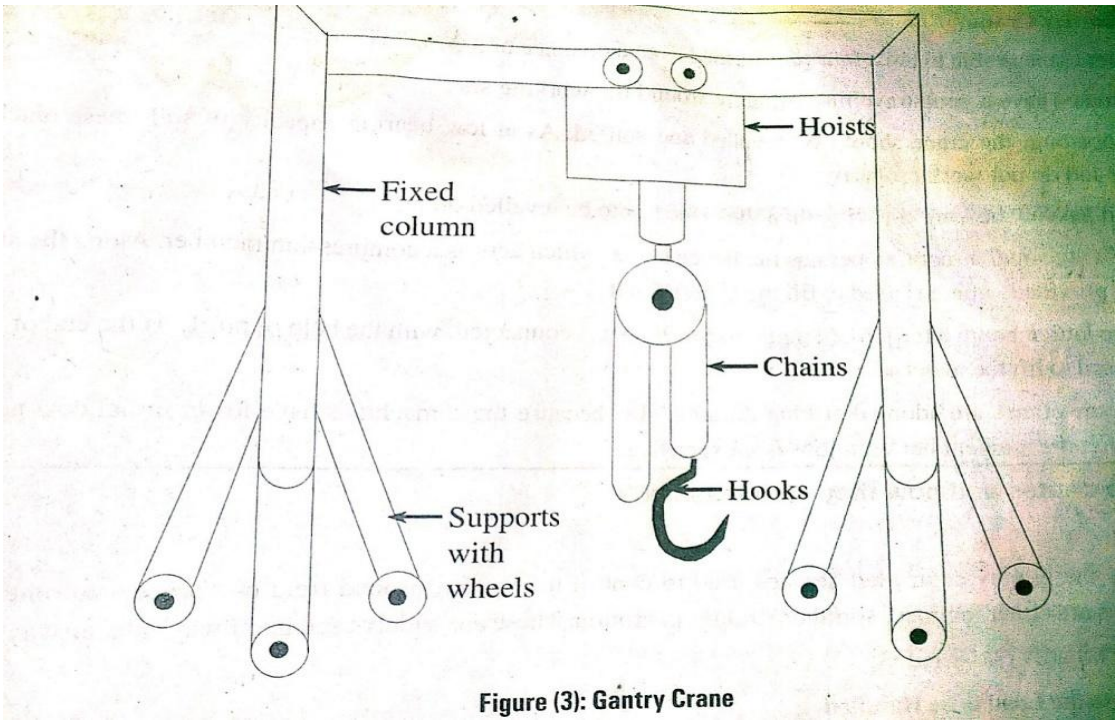


Figure (3): Gantry Crane

- **wharf cranes:** These cranes are the versatile machines and are used widely in shipyards and ports. The capacity of wharf cranes is of 3 to 20 tons.

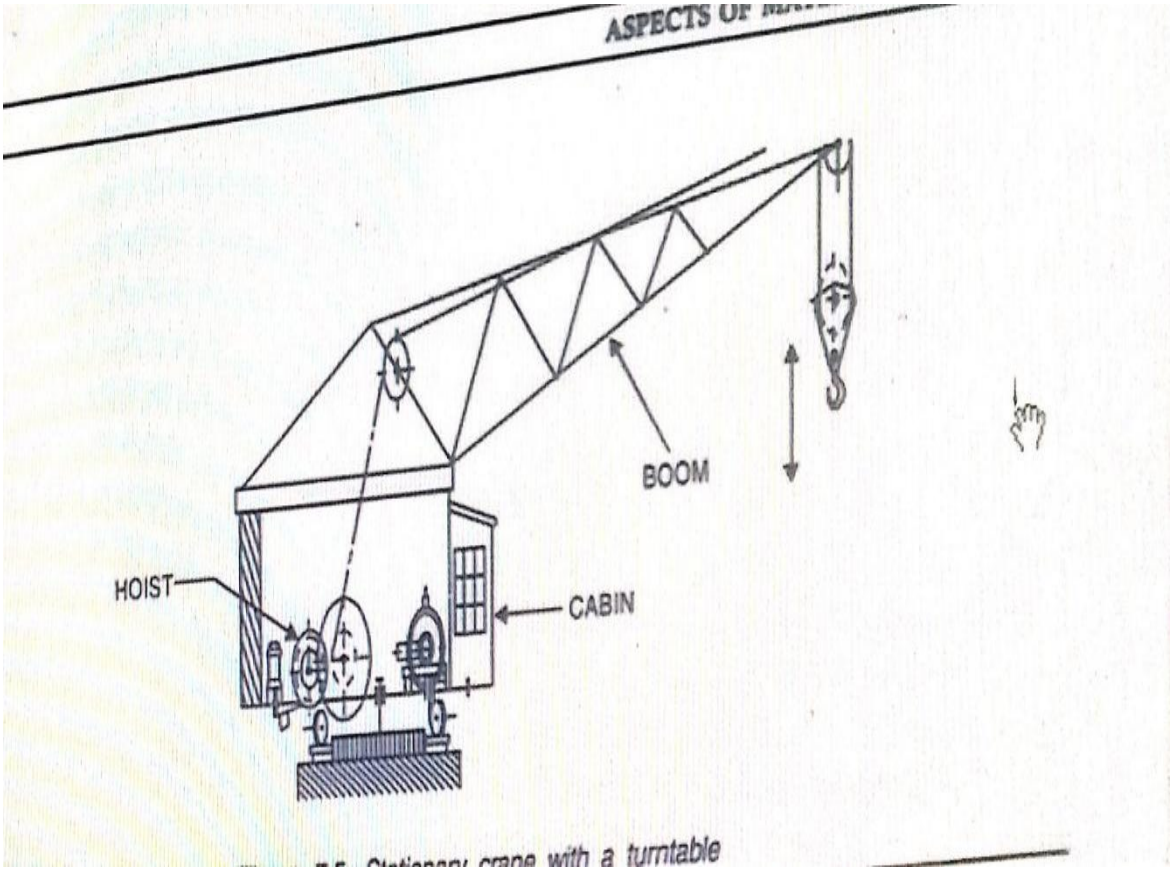


Figure: Wharf crane

iv). ELEVATING SYSTEMS OR EQUIPMENT

In this type of equipment or systems the materials are moved in verically up or down directions. Power driven mechanism us used for raising and lowering the materials. The flow can be continuous or reciprocating motion.

The different types of elevating systems are as follows.

- **Drum type elevators:** These are drum type light duty elevators. These elevators are flexible so that a hoist can be placed in any direction. It is limited to high heights due to the presence of counter weights.
- **Traction type elevators:** These elevators are used instead of drum type elevators. The counter weights attached to the elevators are balanced by means of electric motors.
- **Bucket elevators**: This type of elevator transfers bulk materials by means of power driven mechanisms either chain driven or belt driven. These are simple, reliable and are widely used in coal, coke, foundry industries.

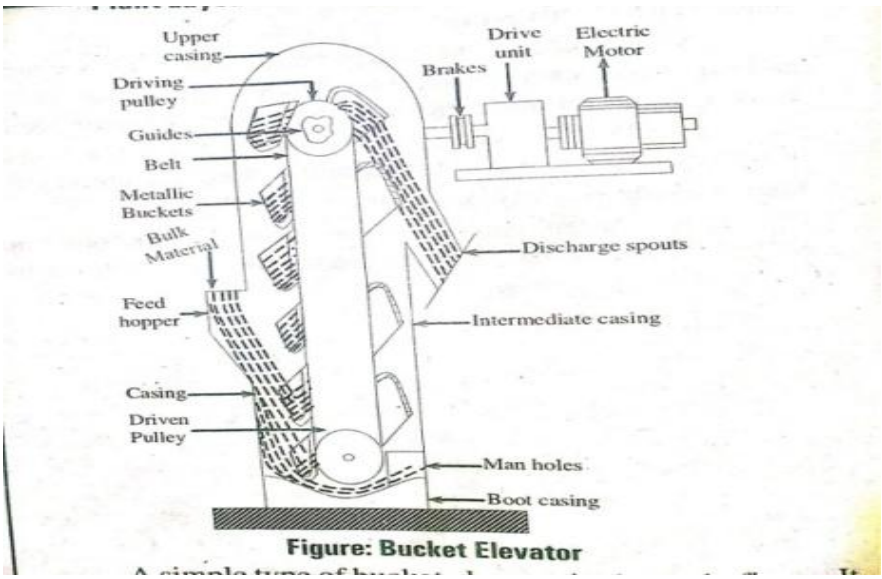


Figure: Bucket Elevator

4.5 EXPLAIN PATH ORIENTED MATERIAL HANDLING SYSTEM OR EQUIPMENT

In this type, the Equipments are classified based on the path of handling
Elements of handling equipment: The different elements of handling movements are as follows.

i. The path followed
ii. The course followed.
iii. The type of motion followed.

i. The path followed: The path followed for material handling is tabulated as follows.

Movement Type	Representation	Angle of Inclination
Horizontal	→	0°
Vertical	↑	90°
Inclined	↗	<+90°
Declined	↘	<–90°
Straight(Plan view)	——	–
Curved (Plan view)	⌒	–

Road ways are represented by horizontal paths. When there is a slight pitch , then it is represented as vertical with slight deviation.

ii. **THE COURSE FOLLOWED:** The freedom of movement of material handling equipment defines the course to be followed. For example, the trolleys in industrial rail road have fixed routes. It can not be deviated from its route even in case of any type of obstruction in the course

In case of power trucks, they do not have any fixed route. It can move any direction as required. This type of course followed is represented in figure

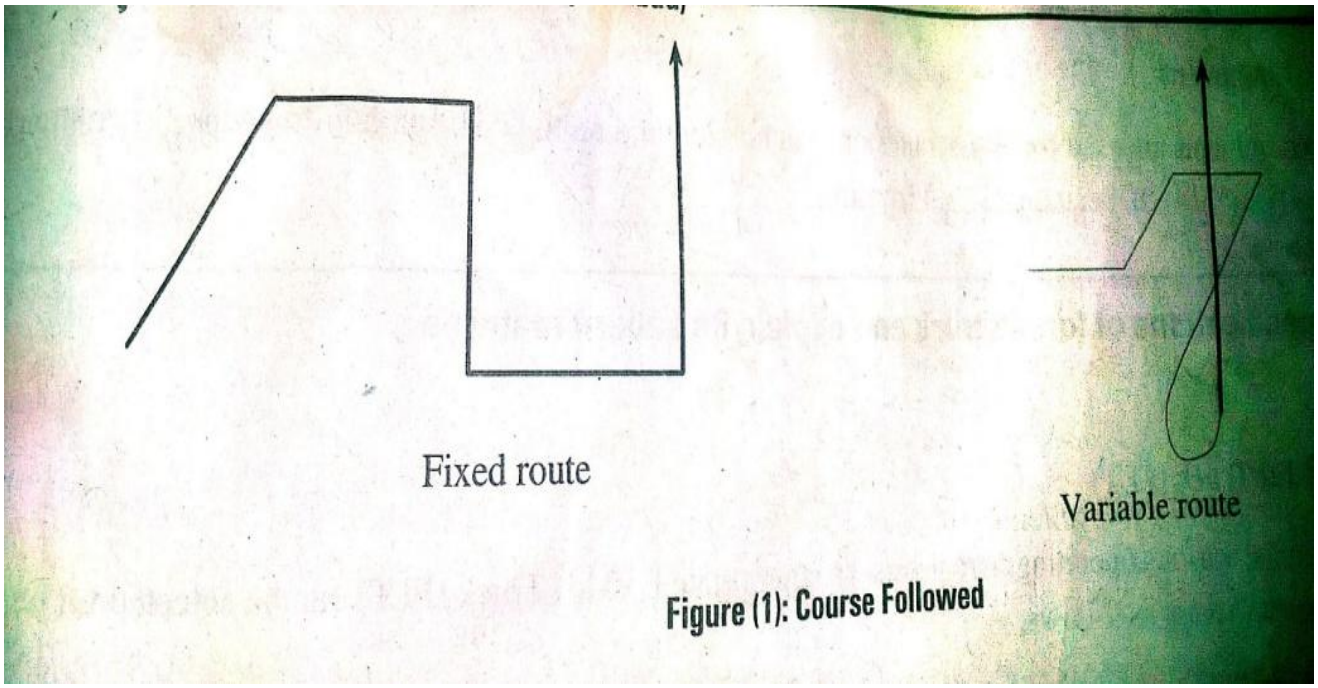


Figure (1): Course Followed

iii. THE TYPE OF MOTION FOLLOWED: the power driven mechanism ensures the type of motion to be followed for material handling.

In case of conveyor belt, the type of motion followed is continuous.

In lifts or elevators, the reciprocating motion is employed.

The intermittent motion follows stop and proceed phenomenon. It neither depends on path nor course followed.

The different types of motions followed are represented by figure which is as follows.

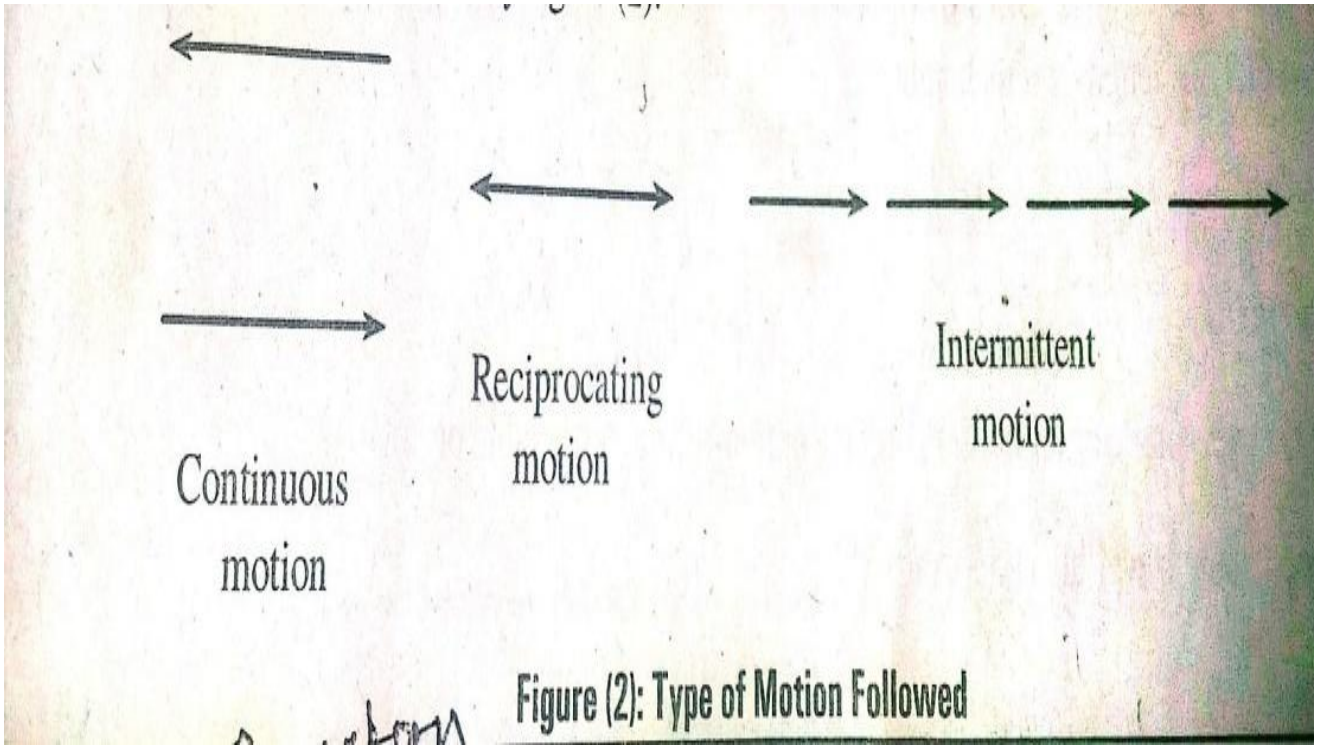


Figure (2): Type of Motion Followed

UNIT – V

5.1 ASPECTS OF ANALYSIS:

Cost analysis is performed to reduce the cost of material handling system. For different plants cost of material handling will be different. The aspects of cost analysis are as follows.

i. cost of handling division.
ii. Handling process as part of the operation.
iii. Individual costs related to handling
iv. Total factory cost of handling

i. Cost of handling Division: The cost of handling division is related to functions within a accountable frame work, which includes tool rooms, receiving shipment, packing, crating, internal transport, storage of raw material, in process and finished goods.

ii. Handling Process as part of the operation: Handling process is an integral part of the operation and it deals with handling, machining, setting or positioning time of the component. Internal handling cost is given by.

Internal handling cost: Labour cost of dept* handling time/ total time.

iii. Individual costs related to handling: Individual costs related to material handling system includes, equipment cost, maintenance cost remuneration to the operators, handlers, fitters, checkers, etc.

iv. Total Factory cost of Handling: The cost of handling in a factory is the sum of cost of handling divisions, handling process as part of the operation and individual costs related to handling.

5.2 VARIOUS COST CONSIDERATIONS IN MATERIAL HANDLING

The different cost considerations involved in material handling Equipments are summarized as follows.

i. Initial cost of equipment
ii. Installation cost
iii. Operating cost
iv. Cost of suppliers, repairs, maintenance etc.
v. Depreciation cost.
vi. Taxes and insurance cost
vii. Obsolescence cost.
viii. Auxiliary equipment cost.
ix. License cost
x. interest on investment cost.
xi. Rental of space
xii. Probable salvage cost

i**. Initial cost of Equipment**: The cost of equipment to be purchased varies from model to model depending upon the operations to be performed. The firm has to bear this cost to meet the requirement according to its standard.

ii. Installation **cost**: Generally, the initial cost is done by the manufacturer. In some cases while installing, the equipment has to be rearranged or if any kind of alteration required has to be done according to the building structure. This cost has to bear by the installer.

iii. **Operating cost:** The cost of operation includes power cost, labour cost, supervision cost, running cost, etc. These cost has to be minimized in order to enhance the productivity.

iv. **Cost of supplies, Repairs, Maintenance etc:** The industry has to bear any failure of the component, repairs or general maintenance cost of the equipment. The maintenance can be carried out by either industry personnel or agency experts. If the maintenance is carried out by industry personnel then, they have to carry inventories and must

train the persons who are involved in this job. Thus, the cost of maintenance will be increased. If the maintenance is carried by agency experts then, the cost of maintenance will be reduced.

v. **Depreciation cost:** The cost starts when the equipment is installed and operating at full swing. It mainly deals with replacing the old equipment with a new one. It should be kept as low as possible.

vi. Taxes and insurance cost: The local taxes and the insurance cost has to be borne by the firm according to state or central government acts.

vii. Obsolescence cost: This cost is similar to that of depreciation cost. It deals with replacing the equipment with a new equipment which is technologically superior to the older one. This cost also should be minimum as possible.

viii. Auxiliary **equipment cost**: It is an optical operating cost such as charging of truck batteries, etc. This is required for efficient working of the system and to improve the productivity. It also increases the life of equipment.

ix. **License cost:** The equipment which is to be provided by license such as ,heavy trucks, etc. The licensing cost has to be borne by the firm to operate the trucks.

x. Interest on investment cost: When a firm is not in a position to purchase the equipment then, it has to be taken on a loan. In such cases the interest has to be borne by the firm.

xi. **Rent of space:** The cost of space rented or if equipment is hired for rent comes under this category. Example: Rent of garage space for parking.

xii. **Probable salvage cost:** This cost arises when the equipment is break down and is to be scrapped. This scrapping value should be as high as possible.

5.3 HOW COST OF MATERIAL HANDLING DECREASES BY IMPROVING THE MATERIAL HANDLING TECHNIQUES:

The total cost of material handling can be reduced by improving handling procedure or reducing material handling. The objective to decrease the material handling cost can be achieved by following techniques.

i. Better utilization of space.
ii. Reducing material handling labour
iii. Minimizing the damage of material during material handling.
iv. Material handling should not be handled by skilled or semi-skilled labour.
v. Reduction in process storage
vi Indirect labour expenses should be minimized on activities such as quality control, storage inspection, shipping, tool room, repairing, etc.
vii. Increasing the rate of production.
viii. Decreasing the inventory.
ix. Minimizing the cost on packing and other protective devices.

5.4 SCOPE AND ACTIVITIES OF MATERIAL HANDLING DEPARTMENT:

In large scale industries, material handling activity is very critical for the operation of the plant. Thus, a separate material handling department is established to work independently with its own plans and programmes. The following are some of the scope and activities of material handling department.

i. Design and analysis of new material handling systems or modifying the existing system.

ii. It determines the most efficient and economical methods to transfer the raw materials, semi processed and finished goods to their respective locations.

iii. It establishes certain procedures and plans for receipt, storage, and movement of materials as per the requirement such as raw materials to production department, finished products to the shipment etc.

iv. It deals with the packing and crating of finished product and supplies to shipping.

v. Maintenance of material handling Equipments are dealt by this department.

vi. It provides interplant movement of semi processed products and assemblies.

vii. It undertakes installation and commissioning of material handling equipment.

viii. It facilitates verification and testing of new or modified installations.

ix. It also conducts training programme for employees to know about the operation and maintenance procedure, which also includes, the safety aspects of material handling.

5.4 MATERIAL HANDLING CONSIDERATIONS, INTEGRAL PART OF STORAGE DECISIONS

Material handling is found to be an important constituent of storage space decisions, as it mainly focuses on reducing cost by optimally utilizing the warehousing space. Efficiency of material handling can be improved by considering four essential aspects.

i. Load utilization: In load unitization, material handling must consider a fundamental principle which states that the economy (earnings) of material handling is directly influenced by the size of load handled. Put simply, it is directly proportional to the number of trips ie., as the number of trips increases, more number of labour is required to unload it which in turn increases the cost of stacking. Hence, an entire process can be made economical by reducing the number of trips for materials handling one of the best method is by consolidating the small packages to form a single load which is termed as load unitization. pelletization and containerization are used for the accomplishment of a unit load.

ii. Pelletization: A pallet or a skid is a wooden platform usually used for stacking goods during transportation and storage. It is highly economically to keep the manufactured goods in the form of stocks until the order fulfillment requires bulk breaking . pelletization is also useful in optimal utilization of space optimal utilization space and load unitization.

iii. Containerization: Basically, containers are used for consistent handling of materials and load unitization. Containers are secured and waterproofed large boxes, in which goods are safely placed for transportations and storage. This ability of containers facilities the forms to storage goods even in open yard without making use of ordinary warehouse.

iv. Space layout: As the cost of warehouse is mainly influenced by the location of stocks in warehouses, firm need to maintain a proper balanced between the two, while designing the internal arrangement of warehouses.

v. Layout for storage: While designing a warehouse 'configuration' plays a vital role. If goods are available in large amount for storage, extensive care needs to be taken for their arrangement which is time consuming step. In a warehouse where turnover is low, wide and deep storage are suitable where stocking may be as high as ceiling height with narrow aisles. However, this layout may not be suitable in case of increased turnover which requires wide aisles and decreased altitude of stocks.

vi. Layout for order picking: Order picking means receiving stock from the ware house as per the needs of customer. Order picking is more difficult and consumer much more time than in receiving and storing of the stock. If the turnover is low, then it can simply follow an existing storage areas. But, on the other hand, if the turnover is more , firm has to adapt a modified systematic procedure for breaking the bulk quantity. Basic problem faced by the firms during order picking is that is consumes a lot of time to fill the order which can be reduced to a great extent by either specialized order picking equipment by operational design.

5.5 MAINTENANCE & SCHEDULEED PLAN OF A CONVEYOR SYSTEM

Maintenance of conveyor System: Conveyor system plays a prominent role for material handling. The maintenance of this system must be done with at most care because any defect in the system may result in breakdown of equipment. Thus, effects the productivity of the firm. The maintenance is carried out according to the manufacture's recommendations. The maintenance of conveyor systems are divided into three different categories namely.

i. Inspection
ii. Repair
iii. Overhauling

i. Inspection: Inspection of conveyor system includes complete checking of rollers, belts for tension, wear and tear. Components which require lubrication such as gearbox, bearing etc., are properly lubricated. In this operation, any kind of loose fasteners are fastened and the safety covers are adjusted according to the requirement.

ii. Repair**:** In this process, the components are inspected to rectify the minor defects. The components such as brakes rollers and bets are adjusted or required according to their conditions.

iii. Overhauling**:** In the overhauling process the entire conveyor system is dismantled and defective components are replaced with new one. The components which are worn out and beyond repair as bolts, bearings, oil seal, drum, packing etc., may be replaced . However, the components such as structures, safety guards etc., can be reused either by adjustment or repairing as per their condition.

Typical Maintenance Plan of conveyor System: The following are the components that are inspected during the maintenance plan of conveyor system.

- Inspect the gear box and fill the oil up to the required level.
- Inspect for the general conditions of the system.
- Lubricate the components such as all bearings, pulleys, universal joints, etc.
- Inspect for the sprocket alignment wear and set screw.
- Inspect the tension, wear and lacing in flat belt.
- Inspect the tension, wear and sheave alignment in V-belt.
- Inspect the tension and wear in the chain and lubricate if required.
- Inspect for all the electrical connections at conveyors.
- List out the components to be replaced or repaired.
- Operate and check the entire system after service.

5.6 MAINTENANCE OF CRANES &HOISTS

Maintenance of cranes nd hoists must be carried out only by the authorized persons. It should be processed according to the manufacturer's recommendations. Preventive, maintenance includes lubrication. Safety inspection of brakes, instrumentation, wire ropes, electrical components, etc. The general maintenance of cranes and hoists includes the following operations.

i. Inspection
ii. Repair
iii. Overhauling

i. Inspection**:** During the inspection of cranes and hoists each individual port is inspected for wear and tear. The components which cannot be repaired such as bolts, bearing, wire ropes, etc., are replaced. The components are sufficiently lubricated and the braked are suitably adjusted as per condition.

ii. Repair: The components for minor defects and small repairs are identified after thorough inspection. The machine components which can be effectively operated by minor repairs are processed for repairing operation, or else it is replaced. The components which can be repaired are couplings, trolleys, riveted and bolted joints, etc.

iii. Overhauling: Overhauling of cranes and hoists starts with dismantling of its entire mechanism for maintenance and replacing all the worn out components. The components of sub mechanism are properly aligned and adjusted as per their condition.

5.7 MAINTENANCE OF INDUSTRIAL TRUCKS

Maintenance of industrial trucks is similar to that of a commercial vehicle. This operation can be carried out in a well equipped garage. The maintenance of industrial trucks is divided into three categories namely.

i. Safety inspection
ii. Pre-operation inspection
iii. Periodic Inspection

i. Safety Inspection: Safety inspection of industrial trucks includes, the proper checking of guards, fire extinguisher, rating plate, back rest extension, horn etc.

ii. Pre-operation Inspection: The pre-operation inspection of power trucks includes, checking the fluid levels, conditions of tyres, gauges, horn brakes and hydraulic controls.

iii. Periodic Inspection: In periodic inspection, the truck is periodically inspected for alignment of forks, tightness of components, condition of fan belts, hydraulic system, fuel tank, lift chains, etc.

5.8 ROLE OF SAFETY IN MATERIAL HANDLING: With the advancement in technology in the field of industrial engineering such as, automation, robotics, computerized quality control, etc. Safety has also gained equal importance in the field of engineering. However, the safety is essentially required in material handling operations due to following reasons.

- It may damage the materials property and also hurt the workers, if not handled properly.
- It can also be the cause of breakdown of equipment due to accidents.
- It may result in loss of material, time and damage to atmosphere.

In industries, material handling equipment should be designed according to safety norms and it should be handled with care in order to avoid accidents. The basic causes of accidents associated with the material handling are as follows.

i. Struck by a load
ii. Exceeding the capacity of the equipment.
iii. Improper packing or setup.
iv. Losing control of a load.
v. Physical over exempting the operator.
vi. Improper stacked material.

The accidents related to material handling equipment are mainly caused due to fault of operators. Therefore, the operator must be well trained and motivated about the safety principles. In case of manual material handling, the workers must follow basics of proper work practice, equipment and control. They should be aware of all kinds of accidents that occur during handling. The workers must be capable of eliminating the causes of accidents (at least minimizing it). Then the number of accidents can be reduced in material handling

5.9 SAFETY PRINCIPLES OF MATERIAL HANDLING

Safety principles of material handling indicate that the use of handling methods and equipments must be safe. A safe material handling prefers to handling activity without any hazards either to materials or employees. The handling operation should be accomplished such a way that, the possibility of risk of life and damages to materials are brought

to minimum. This can be achieved by utilizing maximum safety principles or safety policies. Thus the safety principles include the following parameters.

i. The material handling equipment should be provided with sufficient guards and safety devices.
ii. The operator of the equipment must be well trained.
iii. Mechanical handling should be preferred for handling hazardous materials.
iv. Over loading of the equipment should be avoided.
v. The premises of material handling must be kept in good condition.
vi. The materials should be stacked or un-stacked safely.
vii. The floor lighting should be sufficient enough to carry out operation.
viii. Never use any defective equipment.
ix. During material handling, the employees must use personal protective equipment

In order to obtain zero accidental zones, the firm has to strictly follow the safety policies in work place. Though, it consumes more time for its operation, it increases the productivity by zero damage of the materials. This safety policy deals with rules and regulations for manual handling as well as equipment handling. This policy also provide guidelines for various parameters like fire fighting, illumination, maximum load on vehicles, labels, housekeeping, etc. The safety also specifies about the responsibility towards different personal and departmental issues of the company.

5.10 DIFFERENT ACTS AND RULES OF SAFETY & HEALTH REGULATIONS IN INDIA

Acts and Rules of Safety & health regulations: Different countries adapt different safety rules as per their national health and safety standards. In India, there are various acts and rules for safety and health regulations. Some of the most important acts and rules are as follows.

i. Air pollution Act, 1980
ii. Bio-medical waste Rules, 1998
iii. Boilers Act, 1923
iv. Chemical Accidents Rules, 1989
v. Dock workers safety, Health & Welfare Act, 1986.
vi. Explosives Rules, 1983
vii. Factories Act, 1948
viii. Fatal Accidents Act, 1855.
ix. Hazardous wastes Rules, 1989
x. Indian Boilers Regulation(IBR),1950
xi. Indian Electricity Rules, 1965
xii. Indian Fire Act, 1990
xiii. Indian Mines Act and Rules, 1952
xiv. Industries Development and Regulation Act, 1951
xv. Mines and Minerals Development and Regulation Act, 1957.
xvi. Motor Vehicle Act, 1988
xvii. Petroleum Act, 1934
xviii. Petroleum Rules, 1937 and 1976
xix. Radiation Protection Rules, 1971
xx. Static and Mobile Pressure Vessels Act, 1981
xxi. Underground Storage Tank Act, 1990
xxii. Water Pollution Act, 1982

5.11 TRAINING PROGRAMME FOR SAFETY OF MATERIAL HANDLING EMPLOYEES:

Training is very essential for the employees to handle material either manually or with the help of material handling equipment. For the safety of employees, training should be provided prior to the operation of material handling. The initial training should be according to the discretion of the supervisor. A training program includes the following instructions.

i. Proper material lifting techniques for manual handling.

ii. The employees must be aware of different equipments available for material handling.
iii. Proper terminology of different equipments.
iv. The various operating procedures for different types of material handling equipments.
v. Listing of different codes with respect to the corresponding equipment.
vi. Different rules and regulation pertaining to specific types of material handling equipment.
vii. Inspection of the equipment at regular interval.
viii. Proper work practice for handling and the use of safety devices.
ix. Use of appropriate material handling equipment for its suitable task.
x. General maintenance procedures and requirements.

5.12 DIFFERENT ACCIDENTS ENCOUNTERED BY FORK LIFT TRUCK AND ITS USES

Accidents by Fork Lift Trucks (FLT): The different accidents that are encountered by FLT are as follows.

i. Loads being dropped/pushed onto employees.
ii. Overturning of trucks.
iii. Collision with static elements or knocking them on other employees.
iv. Employees being hit by the FLT
v. Trapping injuries.

Causes of Accidents by Forklift Truck

The main causes for these types accidents encountered by FLT are as follows.

i. Operators fault.
ii. Instability of load caused by shift in the centre of gravity.
iii. Using trucks for unsuitable premises.
iv. Lack of clear visibility.
v. Due to insufficient skills of drivers and other employees working in the regions where FLT is being used.
vi. Due to poor communication among employees working in that area.
vii. Due to improper layout and markings on the premises.
viii. Inadequate ventilation and battery charging.
ix. Lack of maintenance of FLT
x. using FLT for unsuited tasks.
xi. Due to over speed of trucks with heavy loads.

5.13 SAFETY PARAMETERS CONCERNED WITH CONVEYOR BELT MATERIAL HANDLING SYSTEM.

Safety parameters in Conveyor Belt System:

In a belt conveyor system, the belt runs at an average speed of 100 meters per minute. For an average person it takes at least of about '1' second to react to an unexpected session. By the time , the person reacts, the belt moves about a distance of 1.6 m and thus it will be very difficult for the employee to remove any kind of tool, cloth, gloved or bare hand, etc. Hence conveyor system with high speed is dangerous and leads to accidents. In order to avoid severe accidents related to conveyor system, the following safety parameters must be followed.

i. while the belt is in operation, do not perform any type of work which expose a pinch point like, clearing a caked material from a roller.
ii. Before starting the equipment, ensures that all the personnel is cleared from conveyor system.
iii. Always keep loose clothing, body parts and hair away from the conveyors.
iv. Do not modify or remove the conveyor controls, without manufacturer's approval.
v. Maintenance of conveyor system should be performed only when electrical, hydraulic, air and gravity energy sources blocked and locked out.
vi. The conveyor and its accessories should be in service or maintain only by the authorized personnel or trained experts.
vii. Ensure that the conveyor is installed with an emergency stop button at each employee's work station.
viii. Do not ride, sit, stand or touch the conveyor at any time.

ix. Ensure that conveyor is operated only with all approved covers and guards in its specified place.
x. when working on a stop belt, if a start up warning is shown, then stop the work immediately and clear the belt.
xi. Ensure that all controls and pull cards are accessible and visible.
xii. Ever try to cross moving belts.

5.14 SAFETY MEASURES FOR OVERHEAD CRANE OPERATION FOR MATERIAL HANDLING

Safety measures for Overhead Crane:

Operation of an overhead crane involves high risk due to its heavy weight and swinging motion, resulting personnel injury, damage to environment etc. Therefore, safety measures must be strictly followed in order to avoid accidents involving several hazards. Some of the safety measures for overhead cranes are summarized as follows.

i. The crane operator must be well trained and competent.
ii. Before its operation, ensure that crane is suitable for carrying the specified loads. Check for the travel, lift, weight, etc.
iii. Inspect the crane physically and visually for any kind of damage, wear and proper functioning of all the mechanism before use.
iv. Make sure that the weight of load (including weight of slings and ropes) should not exceed the capacity.
v. Before starting the lift, all the personnel working under the crane must be warned and ensure that load is not lifted over anyone.
vi. The sling should be inspected before its use and it should not be stored at clean and dry locations on hooks or racks rather than lying on the floor.
vii. A single person must be authorized to signal or communicate with the operator and they must use clear, agreed upon signal.
viii. Ensure that, the crane is installed with automatic and safe load indicator.
ix. The lifting routes should not collide with any other object.
x The height of lifting and length of cranes trolley should be according to load chart.
xi To ensure stability of load, the travel speed should be as slow as possible.
xii Do not leave the crane, while the load is suspended .

5.15 ERGONOMICS OF MATERIAL HANDLING EQUIPMENTS

Ergonomics: Ergonomics is defined as the science which deals with the study of work. It is also concerned with the design of working systems. Ergonomics relates or involves the man, machine and environment in order to increase the efficiency and productivity of the system.

5.16 OBJECTIVES OF ERGONOMICS

i. Developing the correlation between human beings, equipment, working area and environment.
ii. To strengthen the efficiency of work and productivity.
iii. At work situations, upgrading the reliability, prosperity and safety.
iv. To provide the optimal conditions for employees.
v. Reducing the work load physically and enhancing the working attitude.
vi. Assisting the psycho seasonal functions for handling the instruments and promote the job placement of employees.
vii. Avoiding the recollect data which is redundant. For prevention of disease and its effect, the complete study of task is required.

viii. Reducing the cost of each parameter by eliminating the design features which causes the inefficiency and physical disability.

5.17 PRINCIPLES INVOLVED IN ERGONOMICS FOR DESIGNING WORK SYSTEM.

For designing the work systems, the following ergonomics principles are described.

- work task
- work equipment
- work process
- work space
- work environment
- work stress
- work strain
- Work fatigue.

i. Work Task: It plans or proposes the conclusions of work system.

ii. Work equipment: It belongs to apparatus used in work system such as tools, machines, vehicles, devices, furniture installations and other components.

iii. Work process: The work process is concerned with the time sequence and area, where the employees interact with each other, work, equipment, materials, energy and information required.

iv. Work space: Work space is used to determine the volume that is assigned to one or more employees for completing the work task within a work system.

v. work environment: It involves the several factors such as physical, chemical, biological, social and cultural factors that are enclosed by a worker in his/her work place.

vi. Work stress: Work stress involves the addition of conditions and demands in the work system which acts externally to interrupt the physiological and psychological state of workers.

vii. Work strain: The impact of work stress on an employee which is related to each characteristic and capability.

viii. Work fatigue: The non-pathological demonstration of work strain is totally inactive.
