SRM INSTITUTE OF SCIENCE AND TECHNOLOGY ,
KATTANKULATHUR
FACULTY OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF MECHANICAL ENGINEERING

18MEO111T INDUSTRIAL ENGINEERING
VI SEM
UNIT-II PLANT LAYOUT & SELECTION

The geographical location of the final plant can have strong influence on the success of the industrial venture.

Care must be taken in selecting the plant site, and many different factors must be considered.

Primarily the plant must be located where the minimum cost of production and distribution can be obtained but, other factors such as room for expansion and safe living conditions for plant operation as well as the surrounding community are also important.

The location of the plant can also have a crucial effect on the profitability of a project.

The choice of the final site should first be based on a complete survey of the advantages and disadvantages of various geographical areas and ultimately, on the advantages and disadvantages of the available real estate.

The factors to be considered Plant Location and site are:

1. Raw material availability.
2. Location (with respect to the marketing area.)
3. Availability of suitable land.
4. Transport facilities.
5. Availability of labors.
6. Availability of utilities (Water, Electricity).
7. Environmental impact and effluent disposal.
8. Local community considerations.
9. Climate.
10. Political strategic considerations.
11. Taxations and legal restrictions

RAW MATERIALS AVAILABILITY:
The source of raw materials is one of the most important factors influencing the selection of a plant site. Attention should be given to the purchased price of the raw materials, distance from the source of supply, freight and transportation expenses, availability and reliability of supply, purity of raw materials and storage requirements.

LOCATION: The location of markets or intermediate distribution centers affects the cost of product distribution and time required for shipping. Proximity to the major markets is an important consideration in the selection of the plant site, because the buyer usually finds advantageous to purchase from near-by sources.

AVAILABILITY OF SUITABLE LAND: The characteristics of the land at the proposed plant site should be examined carefully. The topography of the tract of land structure must be considered, since either or both may have a pronounced effect on the construction costs.

The cost of the land is important, as well as local building costs and living conditions. Future changes may make it desirable or necessary to expand the plant facilities. The land should be ideally flat, well drained and have load-bearing.

TRANSPORT:

The transport of materials and products to and from plant will be an overriding consideration in site selection. If practicable, a site should be selected so that it is close to at least two major forms of transport: road, rail, waterway or a seaport. Road transport is being increasingly used, and is suitable for local distribution from a central warehouse. Rail transport will be cheaper for the long-distance transport. If possible the plant site should have access to all three types of transportation.

AVAILABILITY OF LABOURS:
Labors will be needed for construction of the plant and its operation. Skilled construction workers will usually be brought in from outside the site, but there should be an adequate pool of unskilled labors available locally; and labors suitable for training to operate the plant. Skilled tradesmen will be needed for plant maintenance.
Local trade union customs and restrictive practices will have to be considered when assessing the availability and suitability of the labors for recruitment and training.

VAILABILITY OF UTILITIES: The word “utilities” is generally used for the ancillary services needed in the operation of any production process. These services will normally be supplied from a central facility and includes Water, Fuel and Electricity which are briefly described as follows:

(i)Water: - The water is required for large industrial as well as general purposes, starting with water for cooling, washing, steam generation and as a raw material in the production of sulfuric acid. The plant therefore must be located where a dependable water supply is available namely lakes, rivers, wells, seas.
If the water supply shows seasonal fluctuations, it’s desirable to construct a reservoir or to drill several standby wells. The temperature, mineral content, slit and sand content, bacteriological content, and cost for supply and purification treatment must also be considered.

(ii)Electricity: - Power and steam requirements are high in most industrial plants and fuel is ordinarily required to supply these utilities. Power, fuel and steam are required for running the various equipments like generators, motors, turbines, plant lightings and general use and thus be considered as one major factor is choice of plant site

(6) ENVIRONMENTAL IMPACT AND EFFLUENT DISPOSAL: Facilities must be provided for the effective disposal of the effluent without any public nuisance. In choosing a plant site, the permissible tolerance levels for various effluents should be considered and attention should be given to potential requirements for additional waste treatment facilities.

7)LOCAL COMMUNITY CONSIDERATIONS: The proposed plant must fit in with and be acceptable to the local community. Full consideration must be given to the safe location of the plant so that it does not impose a significant additional risk to the community.

CLIMATE Adverse climatic conditions at site will increase costs. Extremes of low temperatures will require the provision of additional insulation and special heating for equipment and piping. Similarly, excessive humidity and hot temperatures pose serious problems and must be considered for selecting a site for the plant. Stronger structures will be needed at locations subject to high wind loads or earthquakes.

POLITICAL AND STRATEGIC CONSIDERATIONS Capital grants, tax concessions, and other inducements are often given by governments to direct new investment to preferred locations; such as areas of high unemployment. The availability of such grants can be the overriding consideration in site selection.

TAXATION AND LEGAL RESTRICTIONS: State and local tax rates on property income, unemployment insurance, and similar items vary from one location to another. Similarly, local regulations on zoning, building codes, nuisance aspects and others facilities can have a major influence on the final choice of the plant site.

What is an ideal location?

An ideal location is one where the cost of the product is kept to minimum, with a large market share, the least risk and the maximum social gain.

It is the place of maximum net advantage or which gives lowest unit cost of production and distribution.

For achieving this objective, small-scale entrepreneur can make use of locational analysis for this purpose

The **principal factors of Plant layout are** listed below:

.Economic considerations: construction and operating costs.

.Process requirements.

.Convenience of operation.

.Convenience of maintenance.

.Health and Safety considerations.

.Future plant expansion.

.Modular construction.

.Waste disposal requirement

COSTS:

The cost of construction can be minimized by adopting a layout that gives the shortest run of connecting pipe between equipment, and least amount of structural steel work. However, this will not necessarily be the best arrangement for operation and maintenance

PROCESS REQUIREMENTS: An example of the need to take into account process consideration is the need to elevate the base of columns to provide the necessary net positive suction head to a pump.

CONVENIENCE OF OPERATION: Equipment that needs to have frequent attention should be located convenient to the control room. Valves, sample points, and instruments should be located at convenient positions and heights. Sufficient working space and headroom must be provided to allow easy access to equipment.

CONVENIENCE OF MAINTENANCE: Heat exchangers need to be sited so that the tube bundles can be easily withdrawn for cleaning and tube replacement. Vessels that require frequent replacement of catalyst or packing should be located on the outside of buildings. Equipment that requires dismantling for maintenance, such as compressors and large pumps, should be places under cover.

(v) HEALTH AND SAFETY CONSIDERATIONS: Blast walls may be needed to isolate potentially hazardous equipment, and confine the effects of an explosion. At least two escape routes for operators must be provided from each level in process buildings.

(vi) FUTURE PLANT EXPANSION: Equipment should be located so that it can be conveniently tied in with any future expansion of the process. Space should be left on pipe alleys for future needs, and service pipes over-sized to allow for future requirements.

(vii) MODULAR CONSTRUCTION:

In recent years there has been a move to assemble sections of plant at the plant manufacturer's site. These modules will include the equipment, structural steel, piping and instrumentation. The modules are then transported to the plant site, by road or sea.

The advantages of modular construction are:

.Improved quality control. 2. Reduced construction cost.

.Less need for skilled labors on site.

The disadvantages of modular construction are: 1. Higher design costs & more structural steel work. 2. More flanged constructions & possible problems with assembly, on site.

FACILITY LAYOUT

A facility layout is an arrangement of everything needed for production of goods or delivery of services.

A facility is an entity that facilitates the performance of any job.

It may be a machine tool, a work center, a manufacturing cell, a machine shop, a department, a warehouse, etc.

The layout design generally depends on the products variety and the production volumes.

OBJECTIVES OF PLANT LAYOUT

The main objective consists of organizing equipment and working areas in the most efficient way, and at the same time satisfactory and safe for the personnel doing the work.

Sense of Unity.

The feeling of being a unit pursuing the same objective.

Minimum Movement of people, material and resources.

Safety.

In the movement of materials and personnel work flow.

Flexibility.

The main objectives are reached through the attainment of the following facts:

Congestion reduction.

Elimination of unnecessary occupied areas.

Reduction of administrative and indirect work.

Improvement on control and supervision.

Better adjustment to changing conditions.

Better utilization of the workforce, equipment and services.

Reduction of material handling activities and stock in process.

Reduction on parts and quality risks.

Reduction on health risks and increase on workers safety.

Moral and workers satisfaction increase.

Reduction on delays and manufacturing time, as well as increase in production capacity.

All these factors will not be reached simultaneously, so the best solution will be a balance among them

The factors affecting plant layout can be grouped into 8 categories:

)Materials

)Machinery

)Labor

)Material Handling

)Waiting Time

)Auxiliary Services

) The building

)Future Changes

Illustrations 1: Two sites A and B are evaluated in terms of above mentioned two costs as follows:

Costs	Site A (Rs.)	Site B (Rs.)
Cost of establishments:		
Land and Buildings	350000	230000
Equipment	60000	60000
Transport facilities	20000	30000
Cost of operations:		
Materials, freight and carriage	34000	24000
Taxes and insurance	10000	7500
Labour	100000	70000
Water, power and fuel	10000	8000
Total	**584000**	**429500**

Which site is preferable?

Site B would be preferred. Even though some individual costs are less in A compared to B.

Considering the ideal location definition , the site B which gives lowest unit cost of production , B is preferred.

The factor least important t when selecting a location for a new furniture store is

a. The weather of the community
b. The future of the community
c. The other businesses in the community
d. The age distribution of the population in the community

ACTIVITY

Talk to three entrepreneurs, one in manufacturing, one in trade and one in service business. Discuss with them to find out: (a) The factors considered by them in the location decision. (b) How have availability of transportation and labour affected their location decision?

TYPES OF PLANT LAYOUT wrt. Manufacturing units

a) Product or line layout
b) Process or functional layout
c) Fixed position or location layout
d) Combined or group layout

a)Product or line layout:

Machines and equipments are arranged in one line depending upon the sequence of operations required for the product. The materials move form one workstation to another sequentially without any backtracking or deviation.

Here machines are grouped in one sequence. Therefore materials are fed into the first machine and finished goods travel automatically from machine to machine, the output of one machine becoming input of the next.

e.g. in a paper mill, bamboos are fed into the machine at one end and paper comes out at the other end. The raw material moves very fast from one workstation to other stations with a **minimum work in progress storage and material handling**

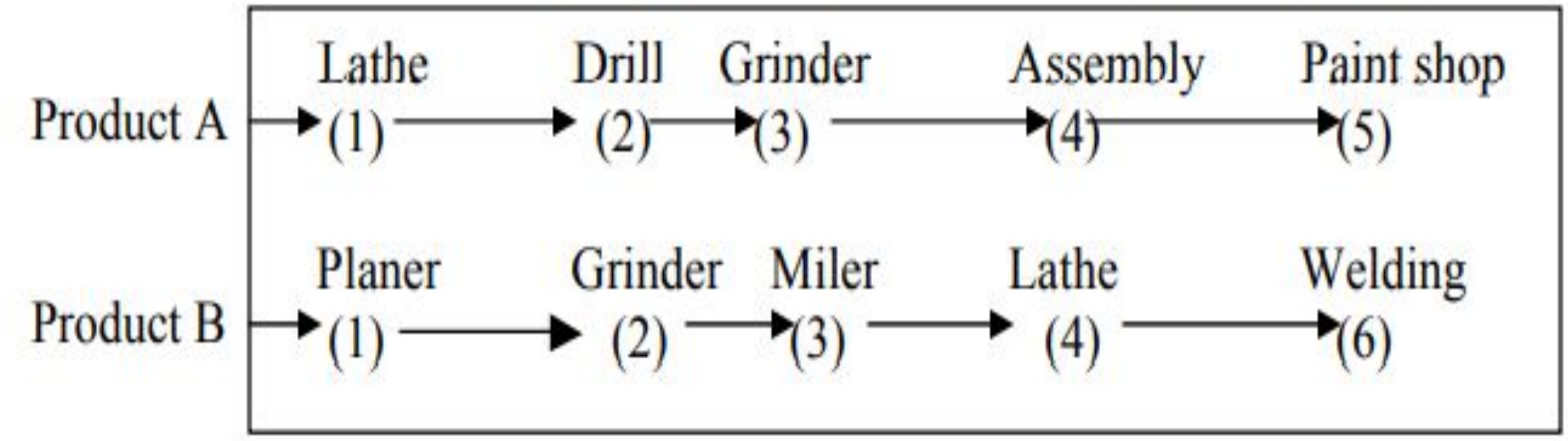
The grouping of machines should be done keeping in mind the following general principles.

All the machine tools or other items of equipments must be placed at the point demanded by the sequence of operations

There should no points where one line crossed another line.

Materials may be fed where they are required for assembly but not necessarily at one point.

All the operations including assembly, testing packing must be included in the line.



Advantages:

)Low cost of material handling.

)Smooth and uninterrupted operations

)Continuous flow of work

)Lesser investment in inventory and WIP.

)Optimum use of floor space

) Shorter processing time or quicker output

)Less congestion of work in the process

)Simple and effective inspection of work and simplified production control

)Lower cost of manufacturing per unit

Disadvantages:

Product layout suffers from following drawbacks:

a)High initial capital investment in special purpose machine.

b)Heavy overhead charges

c)Breakdown of one machine will hamper the whole production process

d)Lesser flexibility as specially laid out for particular product

Suitability: Product layout is useful under following conditions:

)Mass production of standardized products

)Simple and repetitive manufacturing process

3) Operation time for different process is more or less equal

4) Reasonably stable demand for the product 5) Continuous supply of materials .

Eg. chemicals, sugar, paper, rubber, refineries, cement, automobiles, food processing and electronics etc.

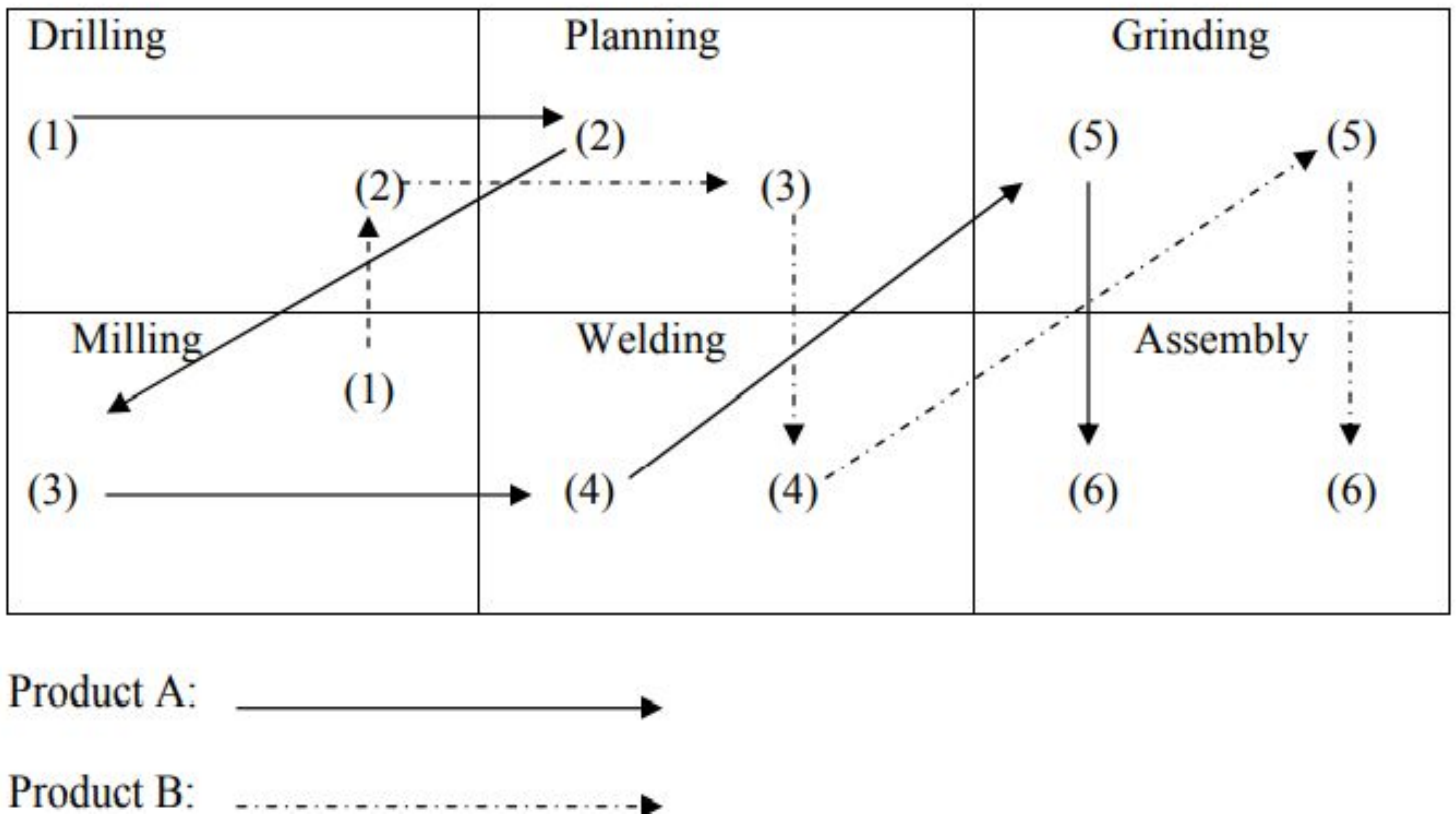
Process layout: Machines of a similar type are arranged together at one place. E.g. Machines performing drilling operations are arranged in the drilling department, machines performing casting operations be grouped in the casting department. Therefore the machines are installed in the plants, which follow the process layout.

Hence, such layouts typically have drilling department, milling department, welding department, heating department and painting department etc.

The process or functional layout is followed from historical period. It evolved from the handicraft method of production.

The work has to be allocated to each department in such a way that no machines are chosen to do as many different job as possible i.e. the emphasis is on general purpose machine.

The work, which has to be done, is allocated to the machines according to loading schedules with the object of ensuring that each machine is fully loaded.


Drilling
Planning
Grinding
(1)
(2)
(5)
(5)
(2)
(3)
Milling
Welding
Assembly
(1)
(3)
(4)
(4)
(6)
(6)
Product A:
Product B:

Advantages:

a) Lower initial capital investment in machines and equipments. There is high degree of machine utilization, as a machine is not blocked for a single product

b) The overhead costs are relatively low

c) Change in output design and volume can be more easily adapted to the output of variety of products

d) Breakdown of one machine does not result in complete work stoppage

e) Supervision can be more effective and specialized

f) There is a greater flexibility of scope for expansion.

e.g. tailoring, light and heavy engineering products, made to order furniture industries, jewelry

Disadvantages:

a. Material handling costs are high due to backtracking

b. More skilled labour is required resulting in higher cost.

c. Time gap or lag in production is higher

d. Work in progress inventory is high needing greater storage space

e. More frequent inspection is needed which results in costly supervision

Suitability:

1. Products are not standardized
2. Quantity produced is small
3. There are frequent changes in design and style of product
4. Job shop type of work is done
5. Machines are very expensive.

Fixed Position or Location Layout:

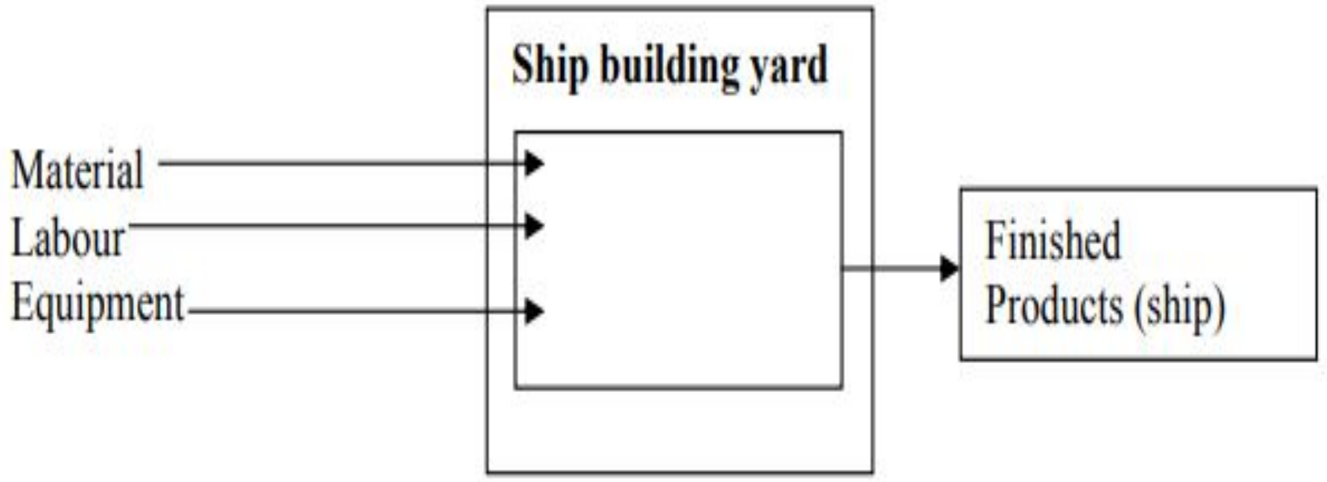
The major product being produced is fixed at one location.
Equipment labour and components are moved to that location.
All facilities are brought and arranged around one work center,not relevant for small scale entrepreneur.

Advantages:

a)It saves time and cost involved on the movement of work from one workstation to another.

b)The layout is flexible as change in job design and operation sequence can be easily incorporated.

c)It is more economical when several orders in different stages of progress are being executed simultaneously.



d) Adjustments can be made to meet shortage of materials or absence of workers by changing the sequence of operations.

Disadvantages:

1. Production period being very long, capital investment is very heavy
2. Very large space is required for storage of material and equipment near the product.
3. As several operations are often carried out simultaneously, Possibility of confusion and conflicts among different workgroups.

Suitability:

1. Manufacture of bulky and heavy products such as locomotives, ships, boilers, generators, wagon building, aircraft manufacturing, etc
2. Construction of building, flyovers, dams.
3. Hospital, the medicines, doctors and nurses are taken to the patient (product).

Combined layout Certain manufacturing units may require all three processes namely intermittent process (job shops), the continuous process (mass production shops) and the representative process combined process [i.e. miscellaneous shops].

In most of industries, only a product layout or process layout or fixed location layout does not exist. Thus, in manufacturing concerns where several products are produced in repeated numbers with no likelihood of continuous production, combined layout is followed. Generally, a combination of the product and process layout or other combination are found, in practice, e.g. for industries involving the fabrication of parts and assembly, fabrication tends to employ the process layout, while the assembly areas often employ the product layout.

In soap, manufacturing plant, the machinery manufacturing soap is arranged on the product line principle, but ancillary services such as heating, the manufacturing of glycerin, the power house, the water treatment plant etc. are arranged on a functional basis.

2. Traders When two outlets carry almost same merchandise, customers usually buy in the one that is more appealing to them.

Thus, customers are attracted and kept by good layout i.e. good lighting, attractive colours, good ventilation, air conditioning, modern design and arrangement and even music.

All of these things mean customer convenience, customer appeal and greater business volume.

The customer is always impressed by service, efficiency and quality.

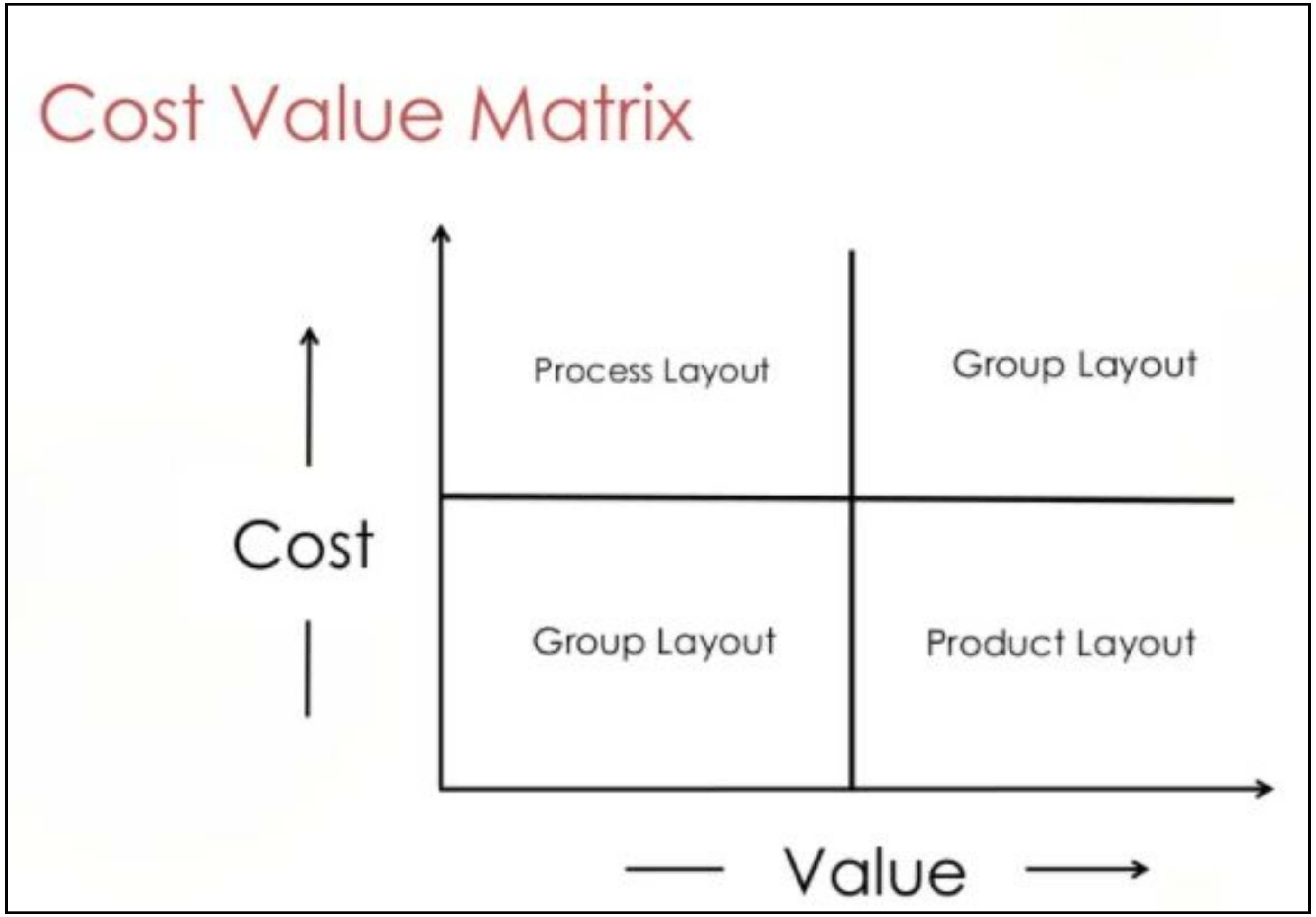
Hence, the layout is essential for handling merchandise, which is arranged as per the space available and the type and magnitude of goods to be sold keeping in mind the convenience of customers.

There are three kinds of layouts in retail operations today.

.Self service or modified self service layout

.Full service layout

.3. Special layouts



Plant layout is a dynamic rather than a static concept meaning thereby if once done it is not permanent in nature rather improvement or revision in the existing plant layout must be made by keeping a track with development of new machines or equipment, improvements in manufacturing process, changes in materials handling devices etc.

But, any revision in layout must be made only when the savings resulting from revision exceed the costs involved in such revision.

Revision in plant layout may become necessary on account of the following reasons:

a) Increase in the output of the existing product

b) Introduction of a new product and diversification

c) Technological advancements in machinery, material, processes, product design, fuel etc.

d) Deficiencies in the layout unnoticed by the layout engineer in the beginning

Tools and techniques for developing layout

Process chart

Flow diagram

String diagram

Template and Scale models

Process Flow Diagrams

- It is an aid to visualize the moment of materials on an existing floor layout.
- A single line is drawn to scale on the floor plan to represent the physical movement of material through the entire plant.
- These show backtracking and excessive movement of materials and helps in relocations of plant activities to reduce travel distance.

Machines data card

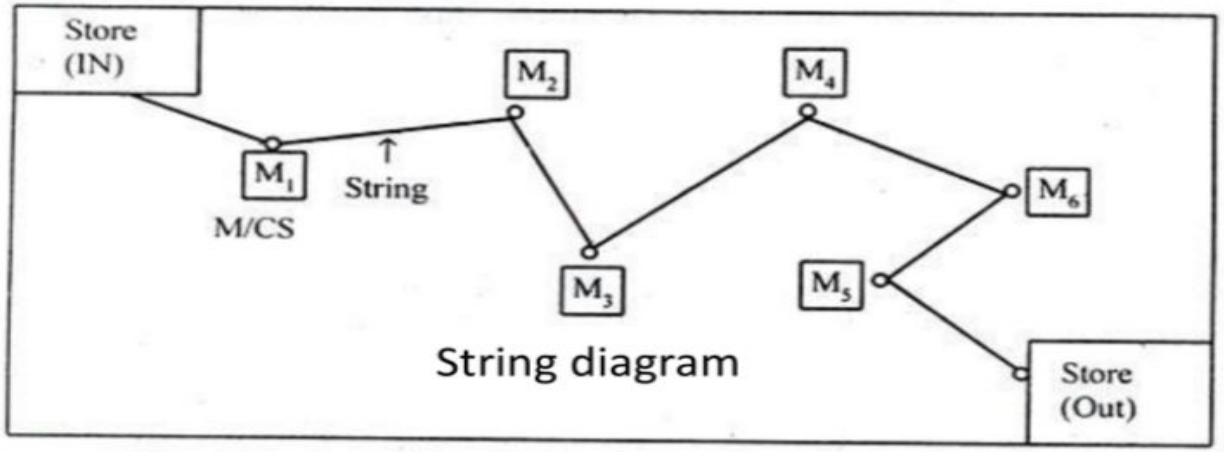
- This card provides full information necessary for the placement and layout of equipment.
- The information generally given on these cards include facts about the machine such as
  - capacity of the machines
  - scape occupied
  - power requirements
  - handling devices required
  - dimensions.

Templates (2D)

- Template is the drawing of a machine or tool cut out from cardboard.
- Cutting to scale shows the actual space utilization.
- The template technique is an important technique because
  - it eliminates unnecessary handlings
  - minimize backtracking of materials
  - it makes the mechanical handling possible
  - it provides a visual picture of proposed or existing plan of layout at one place
  - it offers flexibility to meet future changes in the production requirements

Scale Models (3D)

- One important drawback of template technique is that it leaves the volume, depth, height and clearance of the machines to the imaginations of the reader of the drawing.
- The miniature machines and models of material handling equipment are placed in a miniature plant and moved around to find alternatives.



String diagram

String Diagram

- It can be defined as a scale model on which a thread is used to trace the path or movements of man and materials during a specified sequence of events.

- A thread is used to measure distance, it is necessary that the string diagram should be drawn up to scale.

Steps involved in designing a plant layout

The following are the steps involved in designing a layout:

1. Collection of required data

Data about the size of the plant, type of products to be produced, method of production to be adopted, extent of space available, extent of mechanization etc are to be collected.

2. Preparation of blueprint for the floor plan

Based on the data gathered, a blue print has to be prepared for the floor plan. Care should be taken to ensure, that the layout provides for unhindered movement of men and materials with minimum possible effort and time.

3. Preparation of process chart and flow diagram

The process chart and flow diagram depicting the various activities to be performed and the linkages between them has to be prepared.

4. Preparation of draft layout

A draft layout needs to be prepared clearly depicting the positioning of men and materials and the process flow.

The draft layout should be circulated and discussions held with employees inviting suggestions for improvement.

Flaws pointed out need to be corrected and suggestions received incorporated after due discussions.

5. Test run

A test run is important to understand the efficiency of the layout in a real time work environment. Problems not noticed in the earlier stages can occur at this stage.

The initial problems noticed need to be modified and test runs should be continued for at-least a few times to ensure that the layout is able to facilitate maximum production at minimum cost.

COMPUTERIZED METHODS OF LAYOUT DESIGN

There are two types of algorithms in Computerized methods of Layout Design

1. Constructive Type Algorithm
2. Improvement Type Algorithm

The key element of Computerized Layout planning is the representation & manipulation of the following three types of information:

1. Numeric information: Space required for an activity, total flow b/w two activities
2. Logic information: Preferences of the designer, i.e., the activity relationship chart
3. Graphical information: Drawing of the block plan

Constructive Algorithms are of following types:

.Automated Layout Design Program (ALDEP)

.Computerized Relationship Planning (CORELAP)

The most famous type in Improvement types Algorithms is;

Computerized Relative Allocation of Facilities Technique (CRAFT).

COMPUTERIZED RELATIVE ALLOCATION OF FACILITIES TECHNIQUE (CRAFT)

CRAFT is more popular than the other computer based layout procedures.

It is improvement algorithm & starts with an initial layout & proceeds to improve the layout by interchanging the departments pair wise to reduce the total material transportation cost

It does not give the Optimal Layout; but the results are good & near optimal, which can be later corrected to suit the need of the layout planner.

Features of CRAFT:
i)It attempts to minimize transportation cost, where Transportation cost = flow x distance x unit cost.

ii) It Requires assumptions that:
move cost are independent of the equipment utilization &
move costs are linearly related to the length of the move.

iii)Distance matrix used is the rectilinear distance b/w department centroids .

iv)CRAFT being a path-oriented method, the final layout is dependent on the initial layout. Therefore, a number of initial layouts should be used as input to the CRAFT.

V)CRAFT allows the use of dummy departments to represent fixed areas in the layout

Input Requirements of CRAFT

- .Initial Layout
- .Flow Data
- .Cost per unit distance
- .Total number of departments
- .Fixed departments & their location
- .Area of departments

Procedure adopted for using CRAFT:

- .Determine the department centroids
- .Calculate rectilinear distance b/w centroids
- .Calculate transportation cost for the layout
- .Consider department exchanges of either equal area departments or of departments sharing common border
- .Determine transportation cost of each department interchange

6. Select & implement the departmental interchange that offers the greatest reduction in transportation cost

7. Repeat the procedure for the new layout until no interchange is able to reduce the transportation cost.

Problem 1

Consider the following layout problem with unit cost matrix (as in table1.2). Use CRAFT algorithm to obtain layout. The initial layout is shown in table 1.1 & the flow matrix in table 1.3

7	7	
A	B	7
D	C	7
7	7	

Table 1.1. Initial Layout

Assume the unit cost per Transfer to be 1

Department	A	B	C	D
A		30	25	45
B	20		15	20
C	10	20		10
D	100	10	5	

Table: 1.2.Flow Matrix

Solution:

1. Centroids of the department for given initial layout are as:

   (XA, YA) = 3.5, 10.5

   (XB, YB) = 10.5, 10.5

   (XC, YC) = 10.5, 3.5

   (XD, YD) = 3.5, 3.5

2. **Using the Rectilinear Distance, we draw the distance matrix as shown in table 1.3**

Department	**A**	**B**	**C**	**D**
A	0	7	14	7
B	7	0	7	14
C	14	7	0	7
D	7	14	7	0

Table. 1.3: Distance Matrix

3. **Total material handling cost is calculated as by:**

Total cost = Flow x Distance x Unit cost

Department	A	B	C	D	Cost
A	0	210	350	315	875
B	140	0	105	280	525
C	140	140	0	70	350
D	700	140	35	0	875
				Total Cost	2625

Fig.1.4. Total Cost Matrix

4. Departmental Interchanges:

- Consider various departmental interchanges for improvement
- Departmental interchange is possible for departments having common boundary or equal area

4. Departmental Interchanges:

- Possible Departmental Interchanges are shown in table 1.5

Departmental pair	Reason
A-B	Common border & Equal area
A-C	Equal area
A-D	Common border & Equal area
B-C	Common border & Equal area
B-D	Equal area
C-D	Common border & Equal area

5. For the purpose of calculating material handling cost, interchange would mean change in the centroid. In the same way as we calculated the total cost for the initial layout, we calculate the total cost for each of the possible interchanges, & select the layout that gives the least total cost

CRAFT procedure

S1: Input the details

S2: Compute centroids of departments in the present layout

S3: Form distance matrix using the centroids

S4: Compute the total handling cost

S5: Find all the possible pairwise interchanges of departments based on common border or equal area criterion; For each possibility, interchange the corresponding centroids and compute approximate costs

S6: Find the pair of departments corresponding to the minimum handling cost from among all the possible pairs of interchanges

S7: Is the cost in the previous step less than the total cost of the present layout? If yes, go to S8. If not, go to S11

S8: Interchange the selected pair of departments; Call this as NEW LAYOUT Compute centroids, distance matrix and total cost

S9: Is the cost of new layout less than the cost of the present layout? If yes, go to S10; If not, go to S11

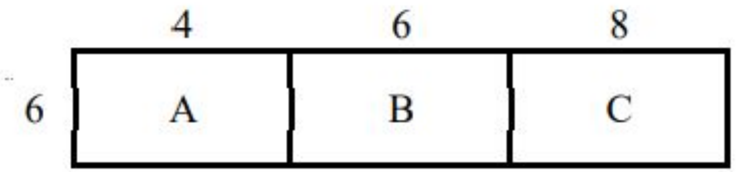
S10: The new layout is here after considered as the PRESENT LAYOUT Its data on centroids, layout matrix, and the total cost is retained Go to S5

S11: Print the present layout as the FINAL LAYOUT S12: Stop

Problem 2:

Consider the following initial layout with unit cost matrix. Use the CRAFT pairwise interchange technique to obtain the desirable layout.

Initial Layout

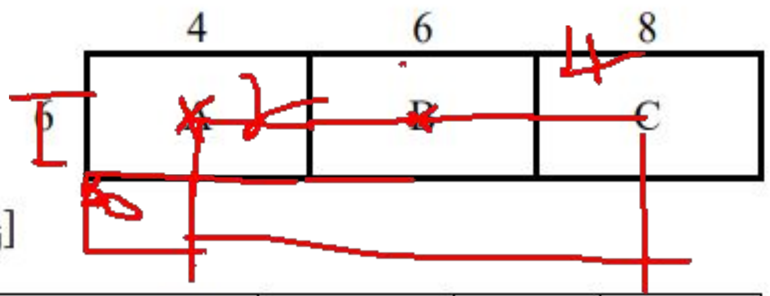


Flow Matrix

From \ To	A	B	C
A	-	1	8
B	2	-	1
C	6	2	-

S1: Total number of departments: 3 Total number of interchangeable departments: 3

Initial Layout:



Cost matrix [c_{ij}]

From \ To	A	B	C
A	-	1	1
B	1	-	1
C	1	1	-

Flow matrix [f_{ij}]

From \ To	A	B	C
A	-	1	8
B	2	-	1
C	6	2	-

Area of departments

Department	A	B	C
Area (Sq. Units)	24	36	48

S2: Centroids of all departments are calculated. Left side and bottom side of the layout are assumed as Y and X axes respectively.

(XA, YA) = (2, 3);

(XB, YB) = (7, 3);

(XC, YC) = (14, 3)

S3: The distance between any two departments is given by rectilinear distance between the centroids of the two departments

dij = |(Xi – Xj) + (Yi – Yj)| where (Xi, Yi) and (Xj, Yj) are the centroids

Distance matrix [d_{ij}]

From \ To	A	B	C
A	-	5	12
B	5	-	7
C	12	7	-

S4: Total cost of handling for the present layout is calculated

Total cost = $\sum \sum fij \times dij \times ci$

Total cost matrix [TC_{ij}]

From \ To	A	B	C
A	-	5	96
B	10	-	7
C	72	14	-

Total cost = 204

S5: Consider various departmental interchanges for improvement.
Departmental interchanges that are possible are given below
Departments having common border and Departments having common area
Pairwise interchanges are considered;
For 3 departments, 3 pairwise interchanges are Possible.

Pair of departments	Remark
A and B	Interchange based on common border
A and C	Not possible
B and C	Interchange based on common border

For the purpose of cost calculation, an interchange between two departments would mean that their present centroids are interchanged.
For each interchange, the associated distance and total cost matrices are calculated

Interchange between A and B
(XB, YB) = (2, 3); (XA, YA) = (7, 3); (XC, YC) = (14, 3)

Distance matrix [dij]

From \ To	A	B	C
A	-	5	7
B	5	-	12
C	7	12	-

Total cost matrix [TCij]

From \ To	A	B	C
A	-	5	56
B	10	-	12
C	42	24	-

Total cost = 149

Interchange between B and C

(XA, YA) = (2, 3); (XC, YC) = (7, 3); (XB, YB) = (14, 3)

Distance matrix [dij]

From \ To	A	B	C
A	-	12	5
B	12	-	7
C	5	7	-

Total cost matrix [TCij]

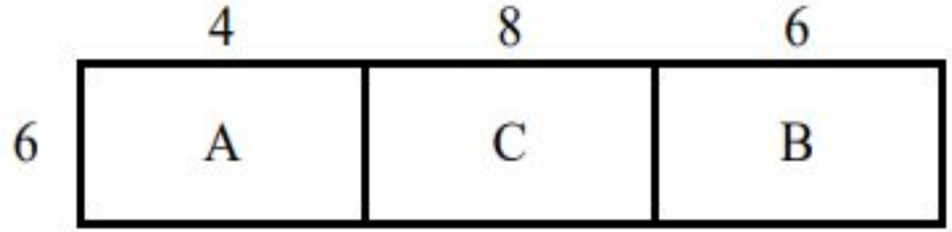
From \ To	A	B	C
A	-	12	40
B	24	-	7
C	30	14	-

Total cost = 127

S6: The interchange which promises minimum handling cost is selected for actual interchange in the layout; interchange between B and C results in minimum cost.

S7: This cost is compared with the cost of the present layout; this cost of 127 is less compared with the cost of 204 for the present layout.

S8: Interchange is made between B and C. New layout is drawn.



The centroids are (XA, YA) = (2, 3); (XB, YB) = (15, 3); (XC, YC) = (8, 3)

Distance matrix [dij]

From \ To	A	B	C
A	-	13	6
B	13	-	7
C	6	7	-

Total cost matrix [TCij]

From \ To	A	B	C
A	-	13	48
B	26	-	7
C	36	14	-

Total cost = 144

S9: The total cost of the new layout is compared with the cost of the present layout
Since the cost is less, the new layout is treated as the present layout.
The process is repeated for the next iteration

AUTOMATED LAYOUT DESIGN PROGRAM (ALDEP)

ALDEP is basically a construction algorithm, but it can also be used to evaluate two layouts.

It uses basic data on facilities & builds a layout by successively placing the layout using relationship information b/w the departments.

Basic Inputs to ALDEP:

.Length & width of facility
.Area of each department
.Minimum Closeness Preference (MCP) Value
.Sweep width
.Relationship chart showing the closeness rating
.Location & size of any restricted area

Procedure Adapted for using ALDEP

Step#1: Input the following

.Length & width of facility

. Area of each department

. Minimum Closeness Preference (MCP) Value

.Sweep width

.Relationship chart showing the closeness rating

.Location & size of any restricted area.

Step#2: One department is selected randomly & placed in the layout

Step#3: In this step, the algorithm uses minimum closeness required b/w departments for the selection of departments to be placed with an earlier placed department. Select the department having maximum closeness rating.

If there is no department having minimum closeness preference then any dept that remains to be placed is selected

Step#4: If all the departments are placed in the layout, go to step#5. else go to step#3

Step#5: Compute the total score of the layout.

Step#6: If the total score required is acceptable score, then go to step#7, else go to step#2.

Step#7: Print the current layout & the corresponding score

Assembly-Line Balancing: An effective tool for improving Productivity

What is assembly-line balancing?

To a workstation within an assembly line in order to meet the required production rate and to achieve a minimum amount of idle time.

Line balancing is the procedure in which tasks along Assigning each task the assembly line are assigned to work station so each has approximately same amount of work.

Unbalance Line and Its effect

High work load in some stages (Overburden)

Maximizes wastes (over-processing, inventory, waiting, rework, transportation, motion)

High variation in output

Restrict one piece flow

Maximizes Idle time Poor efficiency

Balanced Line and its effect

Promotes one piece flow
Avoids excessive work load in some stages (overburden)
Minimizes wastes (over-processing, inventory, waiting, rework, transportation, motion)
Reduces variation
Increased Efficiency
Minimizes Idle time

How Can Assembly-Line Balancing Help Organization

Increased efficiency
Increased productivity
Potential increase in profits and decrease in costs

Steps in Balancing an Assembly Line

.List the sequential relationships among tasks and then draw a precedence diagram.

.Calculate the required workstation cycle time.

.Calculate the theoretical minimum number of workstations.

.Choose a primary rule that will determine how tasks are to be assigned to workstations.

.Beginning with the first workstation, assign each task, one at a time, until the sum of the task times is equal to the workstation cycle time or until no other tasks can be assigned due to sequence or time restrictions.

.**Repeat step 5** for the remaining workstations until all the tasks have been assigned to a workstation.

. Evaluate the efficiency of the line balance.

.Rebalance if necessary

Example of Assembly-Line Balancing Problem:

The Model Z Bicycle is assembled in an assembly line.

Four hundred and twenty bicycles are required each day.

Production time per day is 420 minutes.

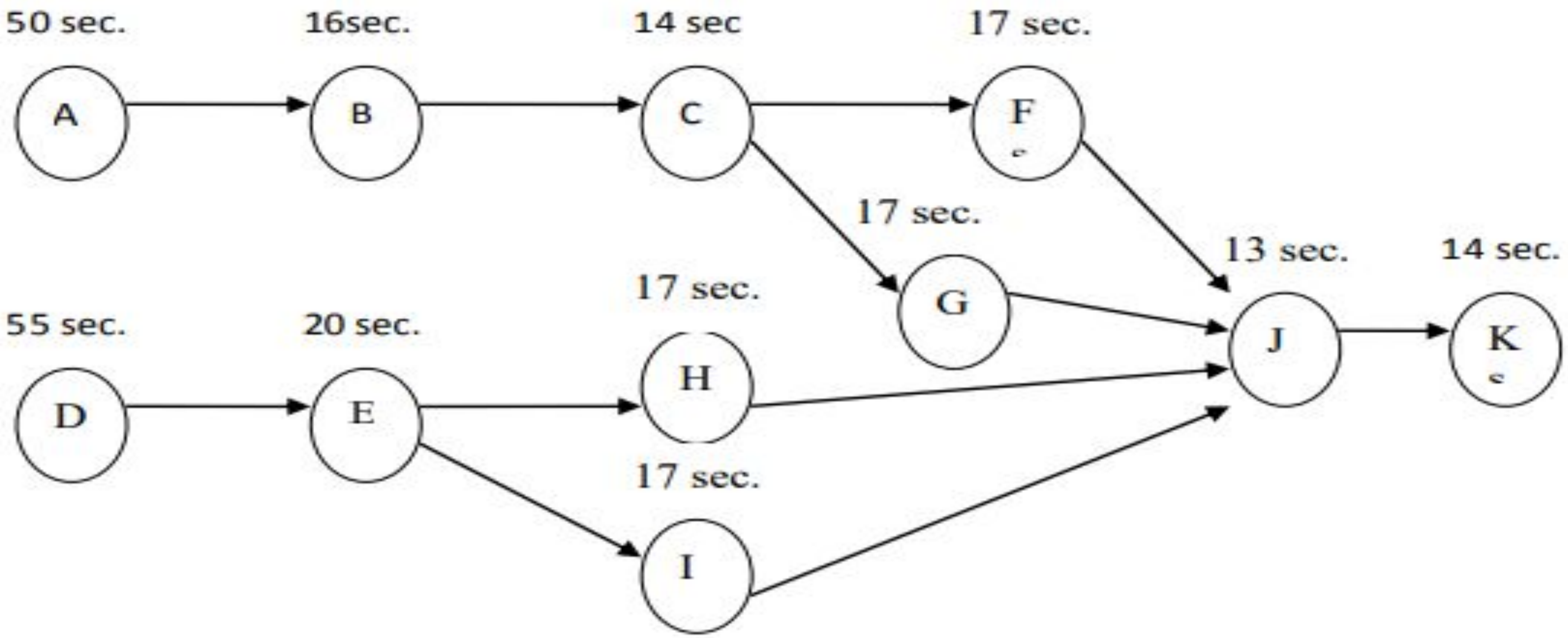
Find the balance that minimizes the number of workstations, that stays within the workstation cycle time limitation, and that complies with task precedent constraints.

Example of Assembly-Line Balancing Cont.

1. Building the Model Z Bicycle: Assembly Steps and Times

Task	Task Time (in seconds)	Task Description	Tasks that must precede
A	50	Connect the front tire to the bicycle frame.	—
B	16	Insert the handle bar.	A
C	14	Tighten handle bar with two screws and nuts.	B
D	55	Connect the rear tire to the bicycle frame.	—
E	20	Position chain mechanism to the frame.	D
F	17	Attach right hand brake to handle bar.	C
G	17	Attach left hand brake to handle bar.	C
H	17	Attach right side pedal.	E
I	17	Attach left side pedal.	E
J	13	Position chain onto chain mechanism.	F,G,H,I
K	14	Attach seat post.	J
	250		

STEP 1. List the sequential relationships among tasks and then draw a precedence diagram



STEP 2. . Calculate the required workstation cycle time

Convert minutes to seconds because task times are in seconds.

CYCLE TIME = (PRODUCTION TIME PER DAY) /(OUTPUT PER DAY)

= (60 sec. X 420 min.) / (420 bicycles)

= 25,200 / 420

= 60 sec.

STEP 3. Calculate the theoretical minimum number of workstations.

NUMBER OF WORK STATIONS = (SUM OF TOTAL TASK TIMES) / (CYCLE TIME)

= 250sec's / 60 sec's = 4.1 = 5 (rounded)

STEP 4.Choose a primary rule that will determine how tasks are to be assigned to workstations

For this example, our primary rule is to prioritize tasks based on the largest number of following tasks.

If there is a tie, our secondary rule is to prioritize tasks in the order of the longest task time. In general, select rules that prioritize tasks according to the largest number of followers or based on length of time

Task	Number of Following Tasks
A	6
B or D	5
C or E	4
F, G, H, or I	2
J	1
K	0

STEP 5. Beginning with the first workstation, assign each task, one at a time, until the sum of the task times is equal to the workstation cycle time or until no other tasks can be assigned due to sequence or time restrictions.

STEP 6. Repeat step 5 for the remaining workstations until all the tasks have been assigned to a workstation

STEP 7.Evaluate the efficiency of the line balance.

EFFICIENCY = (SUM OF ALL TASK TIMES))/(ACTUAL NO OF WORKSTATIONS)X(CYCLE TIME)

= (250) / (5) X (60)

= 0.83 OR 83 %

STEPS 5& 6. Balance made according to the Largest-Number-of-Following Tasks Rule.

Stations	*Task*	*Task Time (in seconds)*	*Number of Following Tasks*	*Remaining Unassigned Time*	*Feasible Remaining Tasks*	*Task with Most Followers*	*Task with Longest Operating Time*
Station 1	**A**	**50**	**6**	**10 idle**	**None**		
Station 2	**D**	**55**	**5**	**5 idle**	**None**		
Station 3	**B**	**16**	**5**	**44**	**C, E**	**C, E**	**E**
	E	**20**	**4**	**24**	**C, F,G, H, I,J**	**C**	
	C	**14**	**4**	**10 idle**	**None**		
Station 4	**F**	**17**	**2**	**43**	**G, H, I**	**G, H, I**	**G, H, or I**
	G	**17**	**2**	**26**	**H, I, J**	**H, I**	**H or I**
	H	**17**	**2**	**9 idle**	**None**		
Station 5	**I**	**17**	**2**	**43**	**J**		
	J	**13**	**1**	**30**	**K**		
	K	**14**	**0**	**16 idle**	**None**		

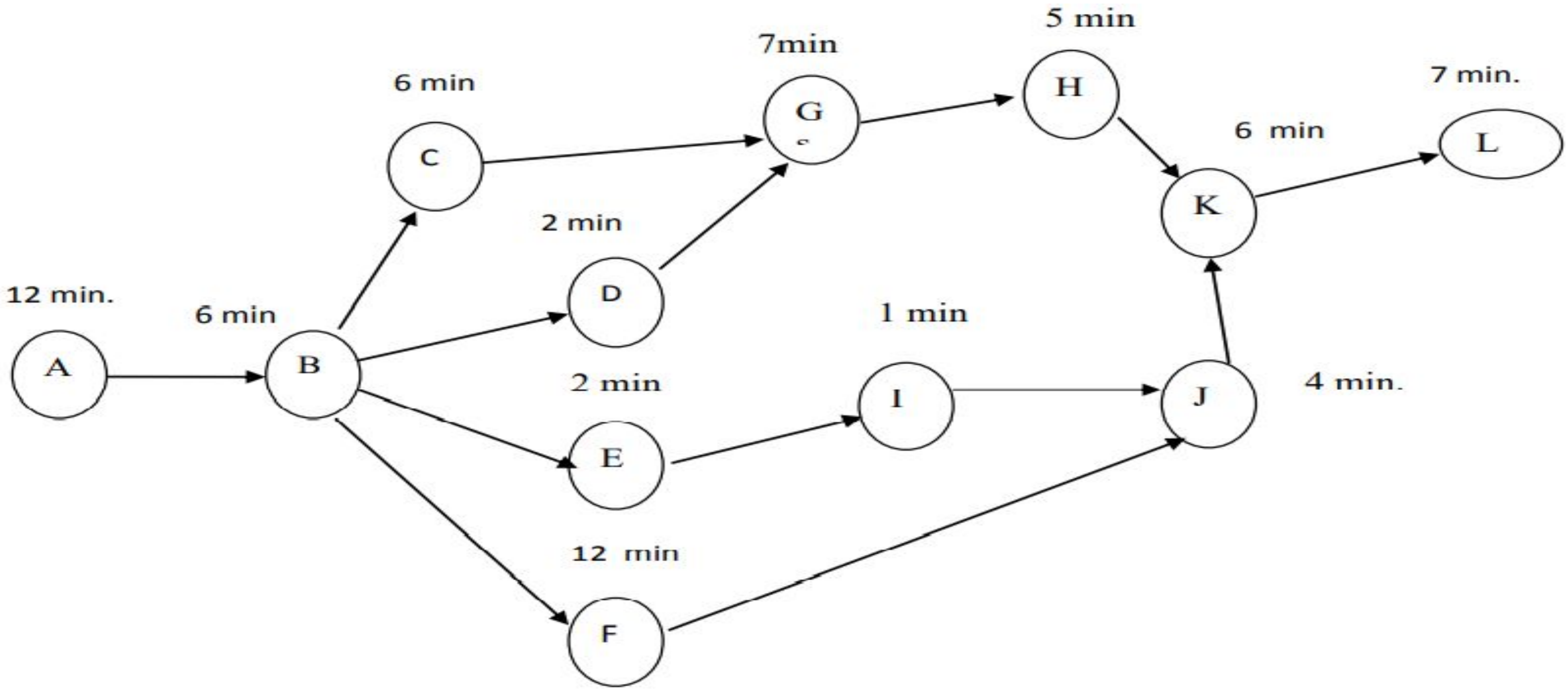
Problem 2: An Assembly consists of the following elements as given in table below. The production rate required is one assembly every 15 minute.

Determine the minimum no of workstations required so as to minimize the Balance-Delay.

Find Balance Delay Station-wise.

Task	A	B	C	D	E	F	G	H	I	J	K	L
Immediate Predecessor	Nil	A	B	B	B	B	C,D	G	E	I,F	H,J	K
Task Time	12	6	6	2	2	12	7	5	1	4	6	7

STEP 1. List the sequential relationships among tasks and then draw a precedence diagram



STEP 2. . Calculate the required workstation cycle time

Cycle time is already glready given as so no need to calculate

CYCLE TIME = (PRODUCTION TIME PER DAY) /(OUTPUT PER DAY)

= 15 minutes

STEP 3. Calculate the theoretical minimum number of workstations.

NUMBER OF = (SUM OF TOTAL TASK TIMES) / (CYCLE TIME)

WORK STATIONS = 70 min's / 15 min's

= 4.67 ≈5 (rounded)

STEP 4.Choose a primary rule that will determine how tasks are to be assigned to workstations

For this example, our primary rule is to prioritize tasks based on the largest number of following tasks.

If there is a tie, our secondary rule is to prioritize tasks in the order of the longest task time.

In general, select rules that prioritize tasks according to the largest number of followers or based on length of time.

Task	Number of Following Tasks
A	11
B	10
C or D or E	4
I,F or G	3
H or J	2
K	1
L	0

STEP 5. Beginning with the first workstation, assign each task, one at a time, until the sum of the task times is equal to the workstation cycle time or until no other tasks can be assigned due to sequence or time restrictions.

STEP 6. Repeat step 5 for the remaining workstations until all the tasks have been assigned to a workstation

STEP 7.Evaluate the efficiency of the line balance.

EFFICIENCY = (SUM OF ALL TASK TIMES))/(ACTUAL NO OF WORKSTATIONS)X(CYCLE TIME)

= (70) / (6) X (15)

= 0.778 OR 77. 78 %

STEPS 5& 6. Balance made according to the Largest-Number-of-Following Tasks Rule

Stations	*Task*	*Task Time (in minutes)*	*Number of Following Tasks*	*Remaining Unassigned Time (Balance-Delay)*	*Feasible Remaining Tasks*	*Task with Most Followers*	*Task with Longest Operating Time*
Station 1	**A**	**12**	**11**	**3 IDLE**	**None**		
Station 2	**B** **C** **D**	**6** **6** **2**	**10** **4** **4**	**9** **3** **1 IDLE**	**C,D,E** **D,E** **None**	**C,D,E** **D,E**	**C** **D ,E**
Station 3	**E** **F** **I**	**2** **12** **1**	**4** **3** **3**	**13** **1** **0 IDLE**	**F,I, G** **I** **None**	**F,I,G**	**F**
Station 4	**G** **H**	**7** **5**	**3** **2**	**8** **3 IDLE**	**H, J** **None**	**H, J**	**H**
Station 5	**J** **K**	**4** **6**	**2** **1**	**11** **5 IDLE**	**K** **None**		
Station 6	**L**	**7**	**0**	**8 IDLE**	**None**		

Material Handling Systems:

The movement of raw materials, semi-finished goods, and finished articles through various stages of production and warehousing is called materials handling. Material Handling is concerned with the movement, storage, and control of materials in a (production) process.

A material-handling system can be simply defined as an integrated system involving such activities as handling, storing, and controlling of materials
Material handling systems range from simple pallet rack and shelving projects, to complex conveyor belt and Automated Storage and Retrieval Systems (AS/RS).

Material handling can also consist of sorting and picking, as well as automatic guided vehicles.
Material handling is the function of moving the right material to the right place in the right time, in the right amount, in sequence, and in the right condition to minimize production cost.

Main objectives

)Reduced Costs

)Increased Capacity

)Improved Working Condition

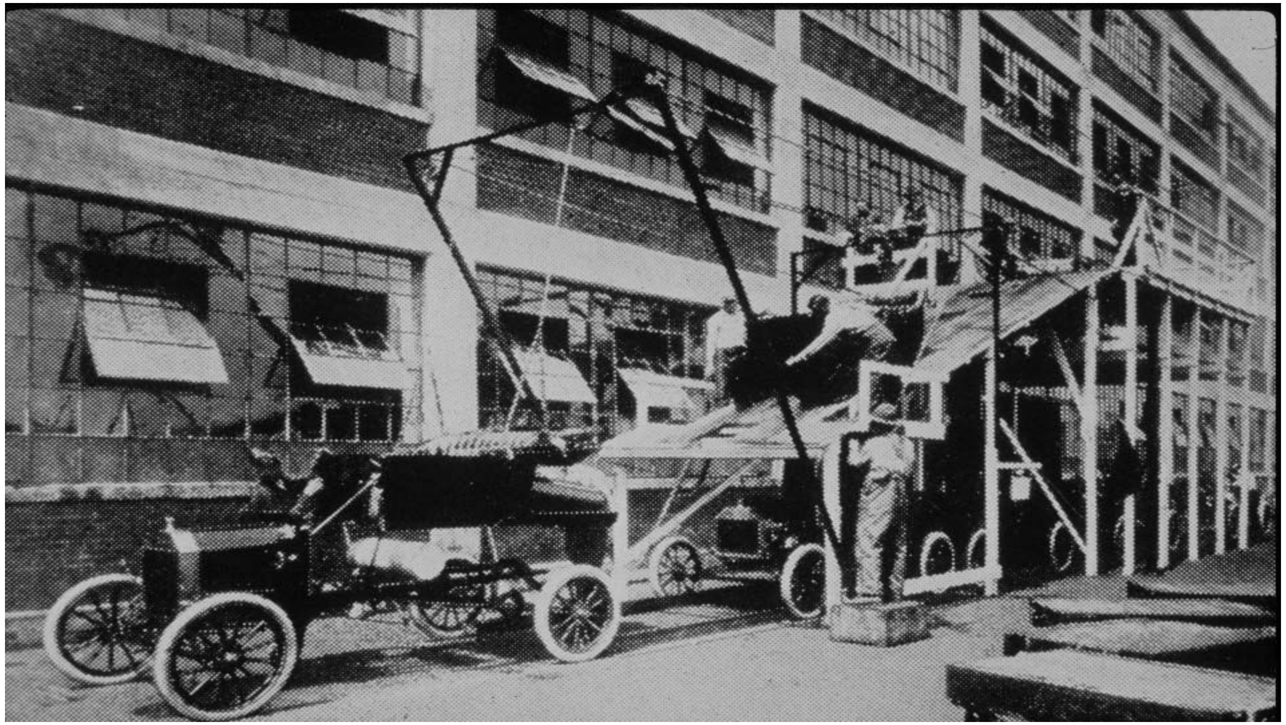
)Value Addition to Products

In brief, the primary objectives of Material Handling are;

.To save money

. To save time

.To save men M



Material Handling in Early Automotive Assembly

Material handling equipment includes:

Transport Equipment: industrial trucks, Automated Guided vehicles (AGVs), monorails, conveyors, cranes and hoists.

Storage Systems: bulk storage, rack systems, shelving and bins, drawer storage, automated storage systems.

Unitizing Equipment: palletizers

Identification and Tracking systems

Scope of Material handling:

Manufacturing	Rail road car builders
Processing	Barge and Ship building
Construction	Aircraft
Mining	
Power	
Machine Tools	
Truck building	

CONSIDERATIONS IN MATERIAL HANDLING SYSTEM DESIGN

.Material Characteristics

.Flow rate

.Plant Layout

1. Material Characteristics

Category	Measures
Physical state	Solid, liquid, or gas
Size	Volume; length, width, height
Weight	Weight per piece, weight per unit volume
Shape	Long and flat, round, square, etc.
Condition	Hot, cold, wet, etc.
Safety risk and risk of damage	Explosive, flammable, toxic; fragile, etc.

2. Flow rate

Quantity of material moved / Move Distance	Short	Long
High	Conveyors	Conveyors AGV train
Low	Manual handling Hand trucks	Powered trucks Unit load AGV

3. Plant Layout

Layout Type	Characteristics	Typical MH Equipment
Fixed – position	Large product size, low production rate	Cranes, hoists, industrial trucks
Process	Variation in product and processing, low and medium production rates	Hand trucks, forklift trucks, AGVs
Product	Limited product variety, high production rate	Conveyors for product flow, trucks to deliver components to stations.

Principles of Material Handling

.Planning Principle
.Standardization Principle
.Work Principle
.Ergonomic Principle
.Unit Load Principle
.Space Utilization Principle
.System Principle
.Automation Principle
.Environmental Principle
.Life Cycle Cost Principle

THE PLANNING PRINCIPLE

Large-scale material handling projects usually require a team approach.

Material handling planning considers every move, every storage need, and any delay in order to minimize production costs.

The plan should reflect the strategic objectives of the organization as well as the more immediate needs.

THE STANDARDIZATION PRINCIPLE

standardize handling methods as well as types and sizes of handling equipment

too many sizes and brands of equipment results in higher operational cost.

A fewer sizes of carton will simplify the storage

UNIT LOAD PRINCIPLE

Unit loads should be appropriately sized and configured at each stage of the supply chain.

The most common unit load is the pallet

cardboard pallets

plastic pallets

wooden pallets

steel skids

SPACE UTILIZATION PRINCIPLE

The better we use our building cube, the less space we need to buy or rent.

Racks, mezzanines, and overhead conveyors are a few examples that promote this goal

THE SYSTEMS PRINCIPLE

MH and storage activities should be fully integrated to form a coordinated, operational system that spans receiving, inspection, storage, production, assembly…, shipping, and the handling of returns.

Information flow and physical material flow should be integrated and treated as concurrent activities.

Methods should be provided for easily identifying materials and products, for determining their location and status within facilities and within the supply chain

AUTOMATION PRINCIPLE

MH operations should be mechanized and/or automated where feasible to improve operational efficiency, increase responsiveness, improve consistency and predictability, decrease operating costs.

EQUIPMENT SELECTION PRINCIPLE

Why? What? Where? When? How? Who?

If we answer these questions about each move, the solution will become evident.

THE STANDARDIZATION PRINCIPLE

standardize handling methods as well as types and sizes of handling equipment.

Too many sizes and brands of equipment results in higher operational cost.

A fewer sizes of carton will simplify the storage

THE MAINTENANCE PRINCIPLE

Plan for preventive maintenance and scheduled repairs of all handling equipment.

Pallets and storage facilities need repair too

THE DEAD WEIGHT PRINCIPLE

- Try to reduce the ratio of equipment weight to product weight. Don’t buy equipment that is bigger than necessary.
- Reduce tare weight and save money.

THE CAPACITY PRINCIPLE

use handling equipment to help achieve desired production capacity

i.e. material handling equipment can help to maximize production equipment utilization

TYPES OF MATERIALS HANDLING EQUIPMENT

Material handling equipment usually falls under four main categories:

Bulk handling material equipment.

Engineered systems

Storage and handling equipment

Industrial trucks.

BULK HANDLING MATERIAL EQUIPMENT

This covers equipment that transports, stores and controls bulk materials.This equipment is used to move and store materials in a loose form. Eg: food, liquid, metal items and minerals.

- **Hoppers:** Hoppers are large funnel-shaped objects with openings that close. Companies use hoppers to pour loose materials into containers.
- **Reclaimers:** Reclaimers are large machines designed to pick up loose materials from a company's stockpile.
- **Conveyor belts:** Conveyor belts are an essential part of a conveyor system. They use drums or pulleys to rotate their belts and move materials in bulk from one location to another.
- **Stackers:** Stackers are key to bulk material handling. This automated equipment can move loose materials to stockpiles on their own.
- **Bucket and grain elevators:** Sometimes referred to as grain legs, bucket elevators vertically move bulk materials.

Hopper

Reclaimer

Conveyors

Stackers

Bucket Elevators

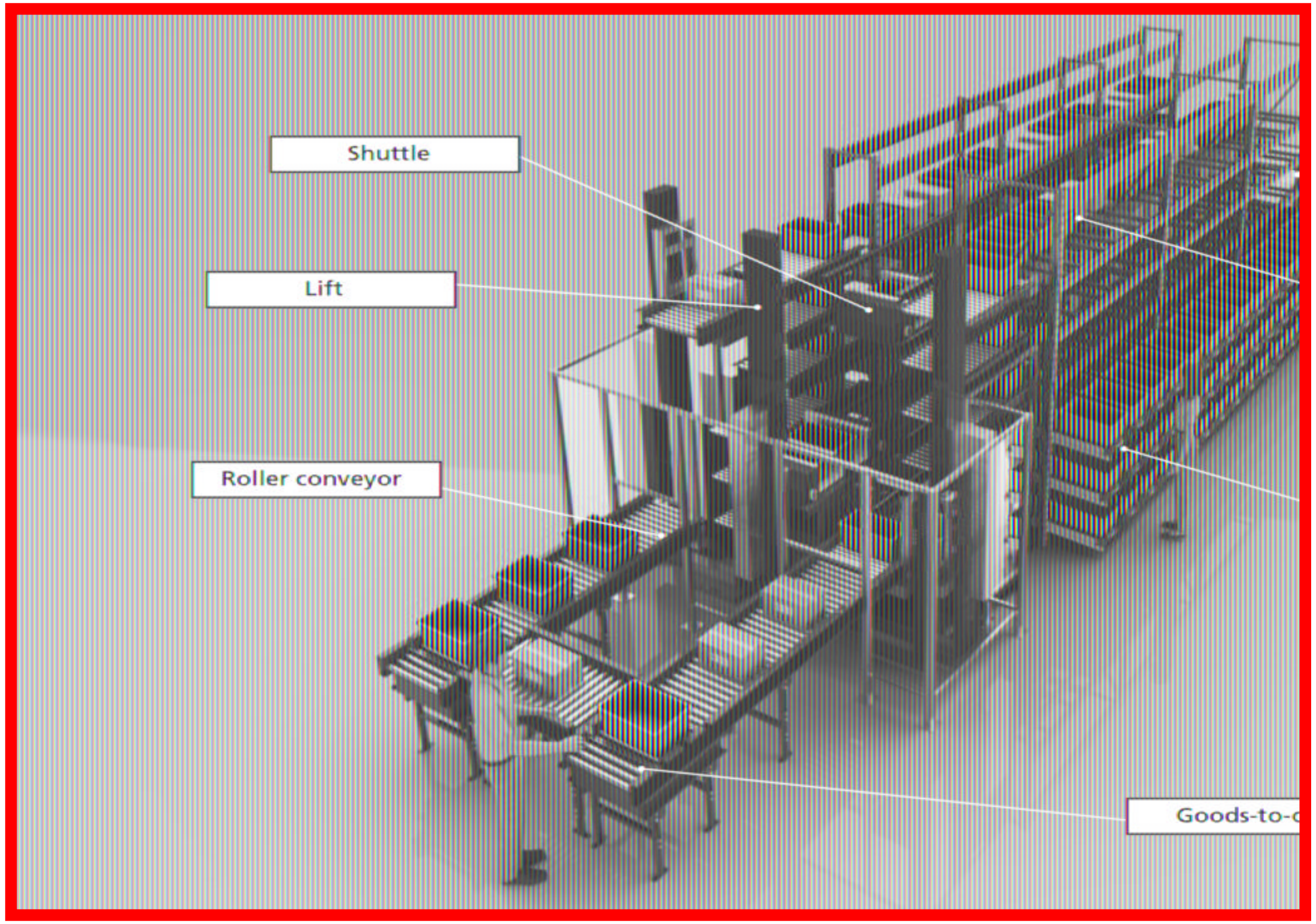
2. ENGINEERED SYSTEMS

Known as automated systems, refer to automated bulk material handling equipment made to help transport and store materials. Usually, automated systems feature several pieces of equipment. Here are some of the primary kinds of engineered systems:

- **Automated Storage and Retrieval Systems (AS/RS):** An AS/RS is a very popular type of engineered system, as it can handle lots of work. It utilizes a shuttle to pick up loose materials and then place them on needed parts of the system, and the picking process can be manually operated or automated. These systems also feature racks, shelves and aisles for easy processing. They can also be connected to a company's network, making it easy for managers to monitor their stock.

- **Automated guided vehicles (AGVs):** AGVs are computer-operated trucks featuring sensors and detectors. These vehicles can be entirely autonomous, moving materials safely around your facility on preset pathways.

- **Robotic delivery systems:** Many facilities utilize automated robotic delivery systems to transport materials. Companies typically use these systems to transport materials on an assembly line.
- **Conveyor systems:** Conveyor systems feature several devices and mechanical assemblies that automatically transport materials throughout a facility. These conveyor systems come in multiple varieties, like apron, cleated, chain, overhead and vehicle conveyor systems.



Automated Storage and Retrieval Systems (AS/RS):

Automated Guided Vehicle

Robot Delivery Systems

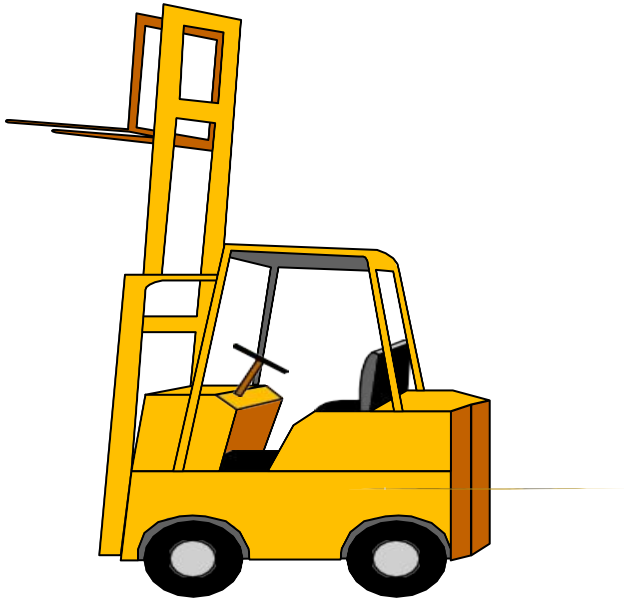
Conveyor System

3. INDUSTRIAL TRUCKS

Industrial trucks cover a wide swath of equipment, and they're all designed to assist with material transportation. These industrial trucks can range from small, hand-operated equipment to large, driveable equipment.

- **Hand trucks:** Hand trucks are commonly called dollies, and they're a simple piece of equipment designed to give operators the leverage they need to roll heavy materials to new locations.
- **Sideloaders:** Manufacturers craft sideloaders to fit between narrow aisles, easily picking up items on either side of them.
- **Pallet trucks:** Otherwise known as forklifts, pallet trucks are machines operators can use to lift heavy pallets. They feature forks designed to slip under the pallet, lift it up and then secure it as the operator takes it to a new location. You can find manual and electrical forklifts in various warehouses around the country.
- **Order pickers:** When operators need to access materials stored up high, they use order pickers. These machines safely lift operators, allowing them to access hard-to-reach materials.

Hand Truck



. Counterbalanced Fork Lift Truck

Riding Hand Truck

Tractor Truck for Trailer Trains

Side loader

Pallet truck

Order Picks

4. STORAGE AND HANDLING EQUIPMENT

Storage and handling equipment helps safely store and organize materials while they await another stage in the production or distribution process. Depending on a company's needs, they may use this storage equipment to hold materials for short or long periods.

Drawers, bins and shelves: You can find shelving used to store and organize basic materials. Bins and drawers are more popular when a company needs to organize smaller materials that could be easily lost otherwise.

- **Mezzanines:** A mezzanine refers to a raised indoor platform that creates another storage area above the ground. These mezzanines help companies store items vertically and free up space on their warehouse floor. They come in modular, rack supported, movable, free-standing and building supported forms.
- **Racks:** Racks help companies store their materials in accessible locations and save floor space. You can find racks designed for various uses, such as sliding racks, drive-in or drive-through racks, pallet tracks and push-back racks.

- **Stacking frames:** Manufacturers design stacking frames to easily stack on top of one another. They're one of the main types of storage equipment in material handling, as they safely store pallets filled with fragile equipment, saving space as a result.

Drawers

bins and shelves

LOCATIONAL(LAYOUT) ECONOMICS

From the following data select the most advantageous location for setting a plant for making transistor radios

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

Solution

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

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

$$\text{RoR for Site X} = \frac{250000-195000}{200000} \times 100 = 27.5\%$$

$$\text{RoR for Site Y} = \frac{(3{,}00{,}000-2{,}15{,}000)}{2{,}00{,}000} \times 100 = 42.5\%$$

$$\text{RoR for Site Z} = \frac{(2{,}50{,}000-2{,}35{,}000)}{2{,}00{,}000} \times 100 = 7.5\%$$

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