# Industrial Management and Engineering Economics

## Chapter 3
### Plant Design

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# What comes in your mind when one talks about plant design?

## Plant Design

- ✓ It is a broad function taking place in the origin of an enterprise.
- ✓ It is the planning of finances, the plant location and all the planning necessary for the physical requirements of an overall design of a plant or factory.
- ✓ The basic **decisions** that must be taken for effective plant design include:

# cont'd

- Product design
- Process design
- Acquisition of capital
- Sales planning
- Make or buy
- Plant Size
- Product price range
- Plant location
- Plant layout
- Diversification
- Building type selection

## I. Product Design:

The design of the product is the foundation upon which a plant layout is built.

- **Design for function:** in order to create a satisfied customer or to attract customers, a product must perform the function for which its customer intends to.
- **Design for manufacturing:** a product that solves the functional problem nicely, but is impossible to manufacture, is worthless.
- **Design for selling:** a product that functions well and easy to make, but wanted by no one is useless.

**II. Process design**: Process planning that is closely allied with plant layout.

**III. Acquisition of Capital**

- Obtaining capital for the initial establishment;
- Raising funds to cover operating costs;
- Secure funds for expansion.

The primary sources of capital are:

- Personal savings;
- Loans and sales of bonds;
- Profit plowback

## IV. Sales Planning:

It is important to know the market demand with the understanding of seasonal variation.

## V. Make or Buy:

The determination of unit cost is usually the first step in a make-buy analysis. In such analysis management is interested in:

- Reducing unit material and processing costs;
- Minimizing cash investment;
- Improving product.

**VI. Plant Size:**

The size of a plant dependent upon the volume of output proposed for it.

**VII. Product Price Range:**

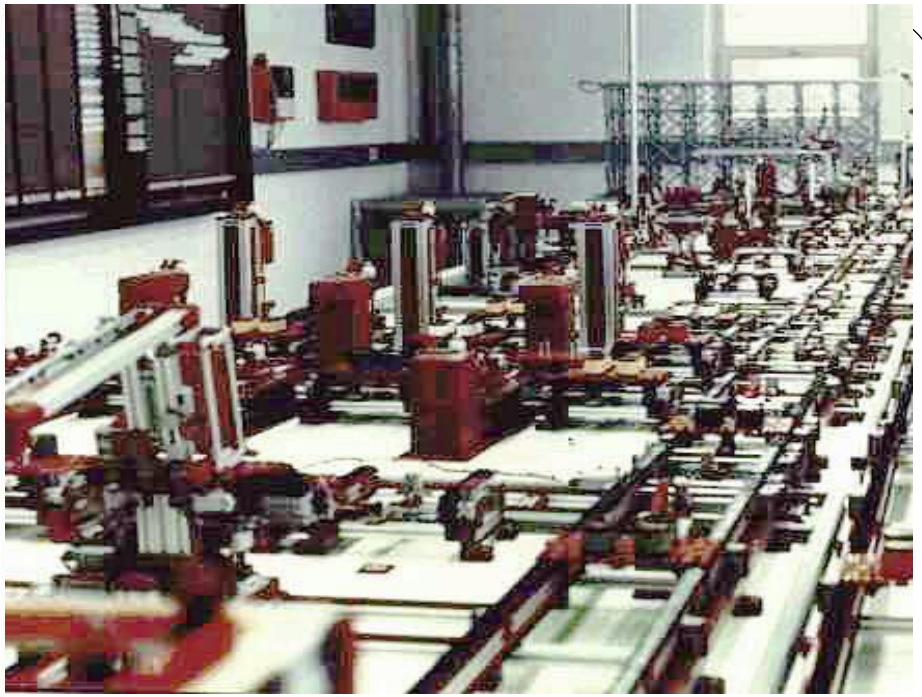
The choice of competent price range will influence the quality, quantity and the manufacturing process of the product.

**VIII. Plant Location:**

Selecting a location involves large commitments of capital as a result it must be done with utmost care.

## IX. Plant Layout:

It is the plan of, or the act of planning, in order to design a good workable disposition of industrial facilities, like operating equipment, storage space, materials handling equipment and all other supporting services, along with the design of the best structure to contain these facilities.

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## X. Building Type Selection:

Selection of the type of building will take place before, or during the plant layout phase.

## XI. Diversification:

To diversify doesn't mean widening the scope of the presently manufactured line, but rather mean entering a completely new field.

## XII. Organization Development:

The manner in which the overall objectives of an enterprise are clearly defined, the objectives of various subdivisions are determined and clearly specified influences the arrangement of plant facilities.

# Plant/Facility location

**What is plant location?**

- Refers to the choice of region and the selection of a particular site for setting up a business or factory.
- To get advantage by virtue of location.
- It is a strategic decision that cannot be changed once taken.
- A **facility** is something built or established to serve a purpose and **facility location** is the determination of the site for that facility. It is part of a larger study area called facility's management, which involves both the location of the facility and the composition, or internal layout of the facility once located.

## Cont'd

There are analytical procedures to aid in the process but the decision must also included factors that are difficult if not impossible to quantify.

**What is an ideal/best 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.

# Selection of general territory

Factors that affect the choice of territory includes:

i. **Location of market:**

Market oriented plants; Space required for output & space required for input. i.e. Car manufacturing, Appliances.

ii. **Cost of construction:**

iii. **Location of raw material:** Raw material oriented factories; weight of input & weight of output.

## iv. 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.

v. **Labors and wages:**

- Quality of labor force
- Availability of labor force
- Unemployment rate
- Labor unions
- Attitudes towards work and labor turnover
- Motivation of workers and work force management

vi. **Energy: other than electric power, in** some plants it is necessary to use gas, coal, fuel-oil, etc…

# Selection of a Specific Site

Factors affecting during selection of a specific site includes:

i. **Community:** the plant has to be located according to the master plan of the city or region.

ii. **Transport:** it is important to consider the transportation infrastructure of the area.

iii. **Availability of utility, electricity, water,……**

- Aluminum plant is strongly dependent to the electricity
- Blast furnace requires a high flow of water

iv. **Future development:** the plant has to be in position to develop or change product quantity, type and size.

iv. **Wind direction:** if the industry produces smoke, gas, odor, etc…

v. **Condition of the site:** the grounds has to have a good resistance to the load induced by the foundation of the building.

vi. **Complementary plants:** an industry to produce as intended, may need material, service and assistance from other plants.

viii. **Cost of living**

- Health care
- Education
- Construction costs.

**Principal factors that must be considered in selecting a suitable plant site and can be summarized as:**

a) Raw material availability.
b) Marketing area.
c) Availability of suitable land.
d) Transport facilities.
e) Availability of labors.
f) Availability of utilities (Water, Electricity).
g) Environmental impact and effluent disposal.
h) Local community considerations.
i) Climate.
j) Political strategic considerations.
k) Taxations and legal restrictions

# Analytic plant location methodology

**1. Location Rating Factor analysis**

Steps for location factor analysis;

1. Identify important factors
2. Weight factors (0.00 - 1.00)
3. Subjectively score each factor (0 - 100)
4. Determine the Sum of weighted scores/ factor rating.
5. Finally select the site which has highest factor rating.

# Location Factor Rating: Example

| LOCATION FACTOR | WEIGHT | SCORES (0 to 100) Site 1 | Site 2 | Site 3 |
|---|---|---|---|---|
| 1. Labor pool and climate | .30 | 80 | 65 | 90 |
| 2. Proximity to suppliers | .20 | 100 | 91 | 75 |
| 3. Wage rates | .15 | 60 | 95 | 72 |
| 4. Community environment | .15 | 75 | 80 | 80 |
| 5. Proximity to customers | .10 | 65 | 90 | 95 |
| 6. Shipping modes | .05 | 85 | 92 | 65 |
| 7. Air service | .05 | 50 | 65 | 90 |

**Weighted Score for "Labor pool and climate" for Site 1 = (0.30)(80) = 24**

Cont.…

# Location Factor Rating

| WEIGHTED SCORES | | |
|---|---|---|
| **Site 1** | **Site 2** | **Site 3** |
| **24.00** | **19.50** | **27.00** |
| **20.00** | **18.20** | **15.00** |
| **9.00** | **14.25** | **10.80** |
| **11.25** | **12.00** | **12.00** |
| **6.50** | **9.00** | **9.50** |
| **4.25** | **4.60** | **3.25** |
| **2.50** | **3.25** | **4.50** |
| **77.50** | **80.80** | **82.05** |

Site 3 has the highest factor rating

**Best Site is 3**

## 2. Center of Gravity Method

- The center of gravity method is used for locating single facilities that considers existing facilities, the distances between them, and the volumes of goods to be shipped between them.
- This methodology involves formulas used to compute the coordinates of the two-dimensional point that meets the distance and volume criteria stated above.

Cont.…

## Center of Gravity Method Formulas

$$C_x = \frac{\sum d_{ix} V_i}{\sum V_i} \qquad C_y = \frac{\sum d_{iy} V_i}{\sum V_i}$$

$C_x$ = X coordinate of center of gravity

$C_y$ = Y coordinate of center of gravity

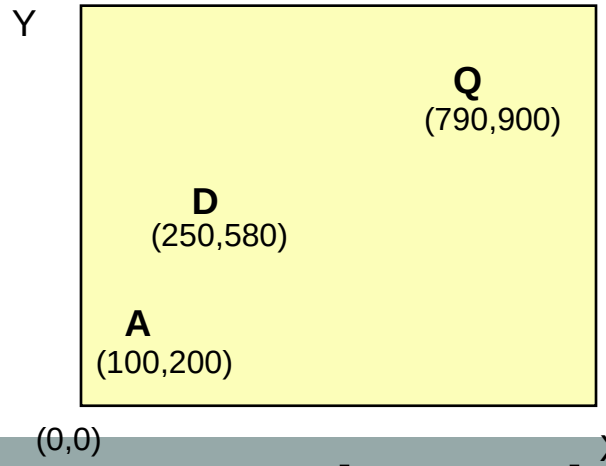
$d_{ix}$ = X coordinate of the ith location

$d_{iy}$ = Y coordinate of the ith location

$V_i$ = volume of goods moved to or from ith location

# Center of Gravity Method Formulas

- Center of gravity method example
  - Several automobile showrooms are located according to the following grid which represents coordinate locations for each showroom.

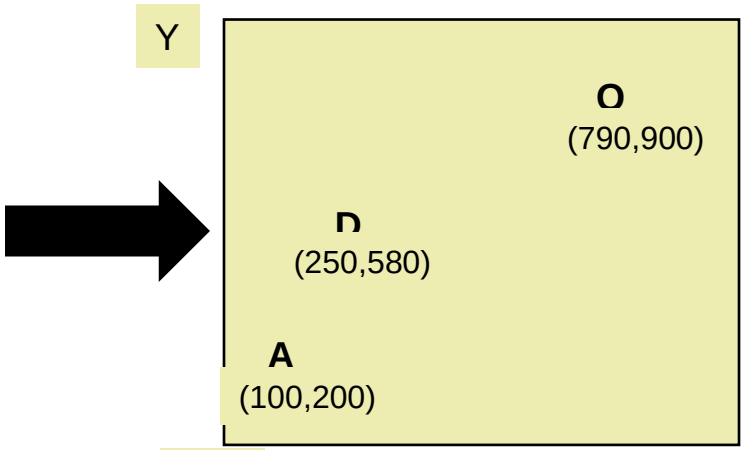



| Showroom | No of Z-Mobiles sold per month |
|---|---|
| A | 1250 |
| D | 1900 |
| Q | 2300 |

Question: What is the best location for a new Z-Mobile warehouse/temporary storage facility considering only distances and quantities sold per month?

# Example of Center of Gravity Method: Determining Existing Facility Coordinates

To begin, you must identify the existing facilities on a two-dimensional plane or grid and determine their coordinates.




You must also have the volume information on the business activity at the existing facilities.

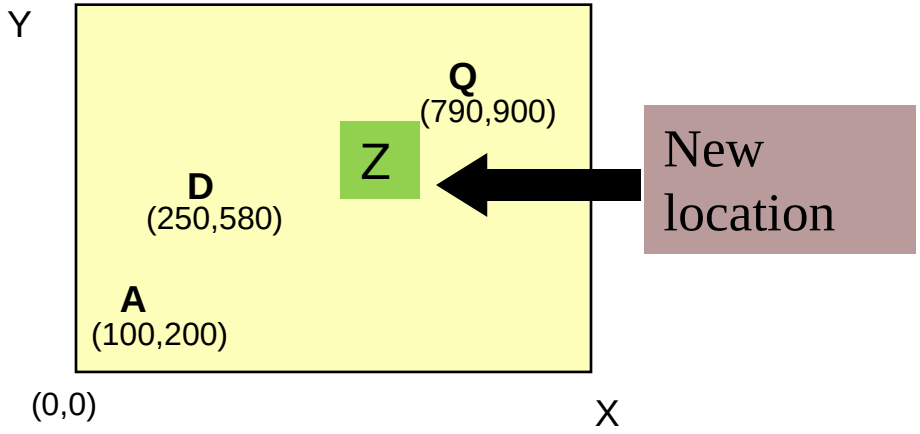
| Showroom | No of Z-Mobiles sold per month |
|---|---|
| A | 1250 |
| D | 1900 |
| Q | 2300 |

# Example of Center of Gravity Method: Determining the Coordinates of the New Facility

You then compute the new coordinates using the formulas:

$$C_x = \frac{100(1250) + 250(1900) + 790(2300)}{1250 + 1900 + 2300} = \frac{2{,}417{,}000}{5{,}450} = \mathbf{443.49}$$

$$C_y = \frac{200(1250) + 580(1900) + 900(2300)}{1250 + 1900 + 2300} = \frac{3{,}422{,}000}{5{,}450} = \mathbf{627.89}$$




| Showroom | No of Z-Mobiles sold per month |
|---|---|
| A | 1250 |
| D | 1900 |
| Q | 2300 |

# Plant layout

- “It is a plan of, or the act of planning, an optimum arrangement of industrial facilities; including personnel, operating equipment, storage space, material handling equipment, and all other supporting services, along with the design of the best structure to contain these facilities.” James M. Moore
- **Plant layout** is the most effective arrangement and coordination of the physical plant facilities to allow greatest efficiency in the combination of men, materials and machines necessary for operation of any unit of a plant or business.

# PRINCIPLES OF PLANT LAYOUT

1. **Principle of overall integration.** The layout is best which integrates the men, material, machinery, supporting activities and any other considerations.
2. **Principle of minimum distance moved.** By placing subsequent operations adjacent to each other, saving can be made reducing the distance of these moves.
3. **Principle of flow.** It means that material will move progressing from one operation to the next towards completion
4. **Principle of cubic space.** Economy is obtained by using effectively all available space both vertical and horizontal.
5. **Principle of satisfaction and safety.** Other things being equal, that layout is best which makes work satisfying and easy for workers.

6. **Principle of Flexibility.** The layout is best when it can be adjusted and rearranged at minimum cost and inconvenience.
7. **Principle of expansion.** Expand in future without disturbing the existing layout and production schedules.
8. **Principle of versatility.** Layout should be adoptable to changes in product design, sales requirement and process improvement.
9. **Principle of orderliness.** Clean work areas with suitable equipment for removing scrap, wastes etc.

# The objectives of a good plant layout

1. **Integrate the production centers**
   - ❖ Integrates (men, materials and machines) in to a logical, balanced and effective production unit.
   - ❖ It permits the arrangement of the equipment to provide greater utilization.
   - ❖ It helps to increase the output by shortening the manufacturing time.
2. **Reduce material handling.** The equipment may be arranged in such a manner to minimize material handling and transportation.

3. **Effective utilization of available space.** The layout determines the location of departments and production centers, their proximity to each other to various services, and hence the efficient utilization of the available space. More over, a good layout utilizes space, both vertical and horizontal in the best possible manner.

4. **Worker convenience and job satisfaction.**

**Ergonomics? human factor engineering**

Working places-safe, well ventilated and free from dust, noise, fumes, odor, and other hazardous conditions helps to increase the efficiency of the workers and improve their morale.

5. **Flexibility:-** the best layout is one, which can be adopted and re-arranged at a minimum cost with least inconvenience.
6. **Avoid unnecessary capital investment:-** Capital investment in equipment can sometimes be reduced by the proper arrangement of machines and departments.
7. **Stimulate effective labor utilization:-** Every year millions of productive man-hours are wasted because of poor layout. Proper layout does not guarantee, but certainly stimulates, the effective utilization of manpower.

# Types of plant layout

**Plant layout can be classified as:**

i. Process or functional layout

ii. Product or line layout

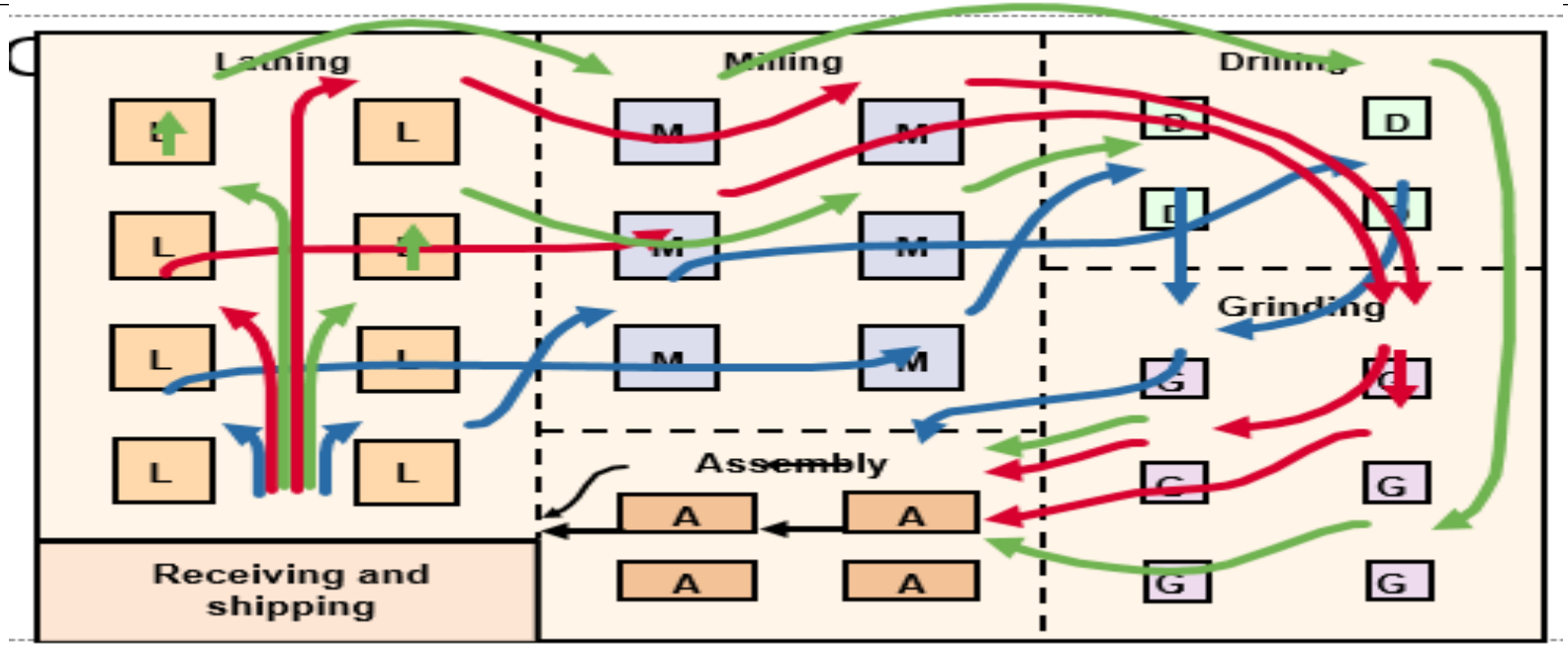
iii. Mixed or combined layout

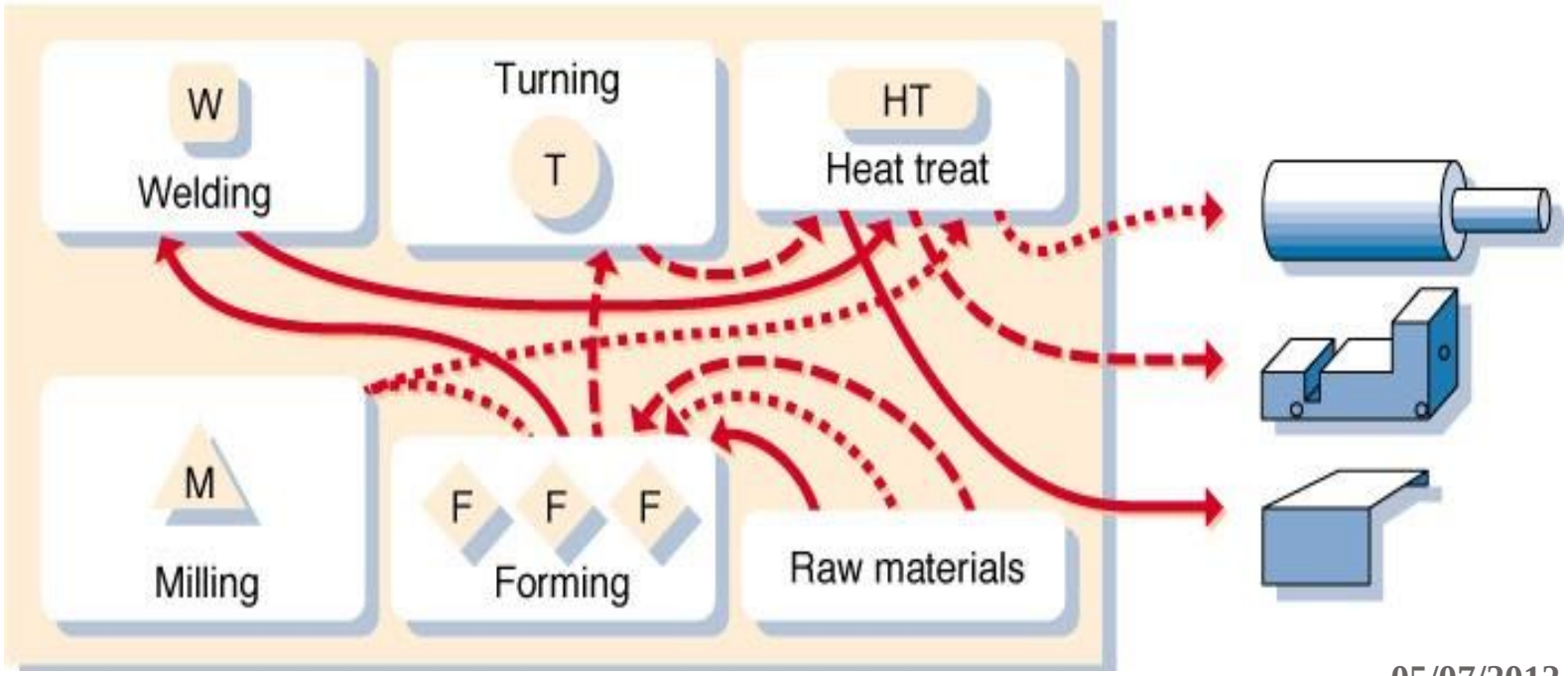
iv. Fixed position layout

v. Group technology layout

# 1. Process (Job Shop) Layouts

- Equipment that perform similar processes are grouped together. e.g., all lathes, milling machines, etc. are grouped in the shop will be clustered in like groups.
- Used when the operations system must handle a wide variety of products in relatively small volumes (i.e., flexibility is necessary)


Lathing
Milling
Drilling
Grinding
Assembly
L
M
D
G
A
Receiving and shipping

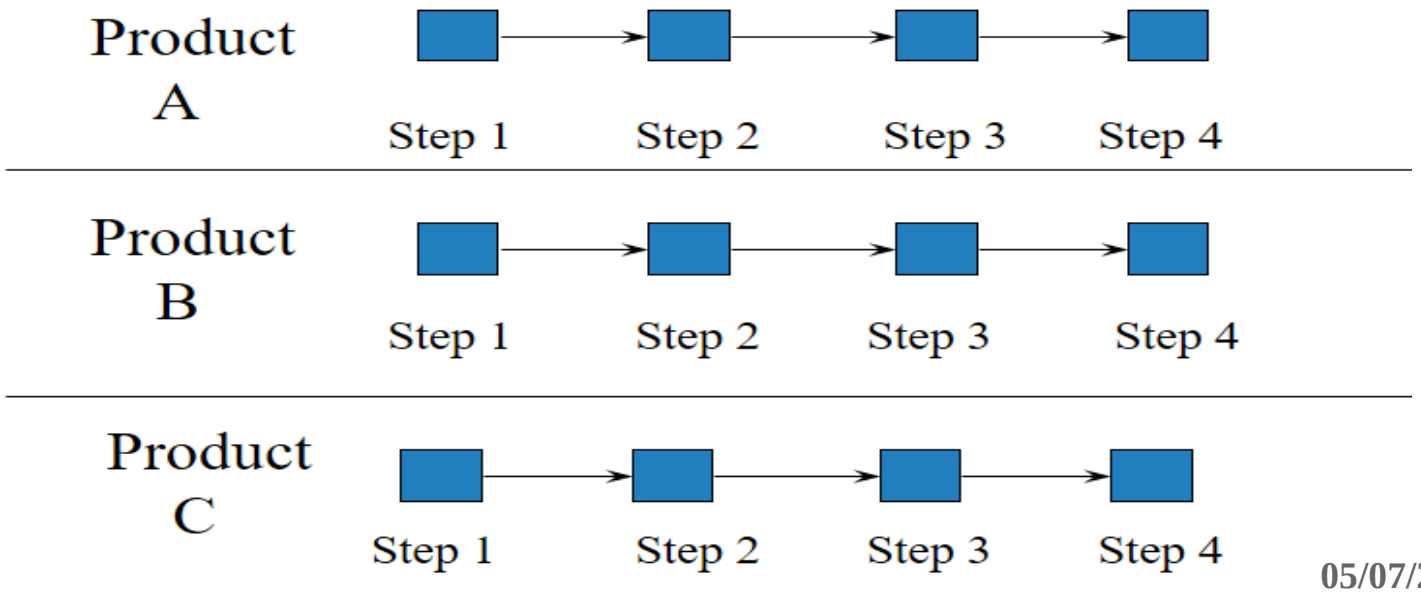

W
Welding
Turning
T
HT
Heat treat
M
Milling
F
Forming
Raw materials

# Characteristics of Process Layouts

- General-purpose equipment is used
- Changeover is rapid
- Material flow is intermittent
- Material handling equipment is flexible
- Operators are highly skilled
- Technical supervision is required
- Planning, scheduling and controlling functions are challenging

# 2. Product (Assembly Line) Layouts

- Operations are arranged in the sequence required to make the product.
- Used when the operations system must handle a narrow variety of products in relatively high volumes.
- Operations and personnel are dedicated to produce one or a small number of products.



# Characteristics of Product Layouts

- Special-purpose equipment are used
- Changeover is expensive and lengthy
- Material flow approaches continuous
- Material handling equipment is fixed
- Operators need not be as skilled
- Little direct supervision is required
- Planning, scheduling and controlling functions are relatively straight-forward
- Production time for a unit is relatively short
- In-process inventory is relatively low

# 3. Mixed or combined layout

- Pure process or pure line layouts are rare. The combination of these is very commonly used in industry.
- The combined layout incorporates the benefits of the process and product layout.

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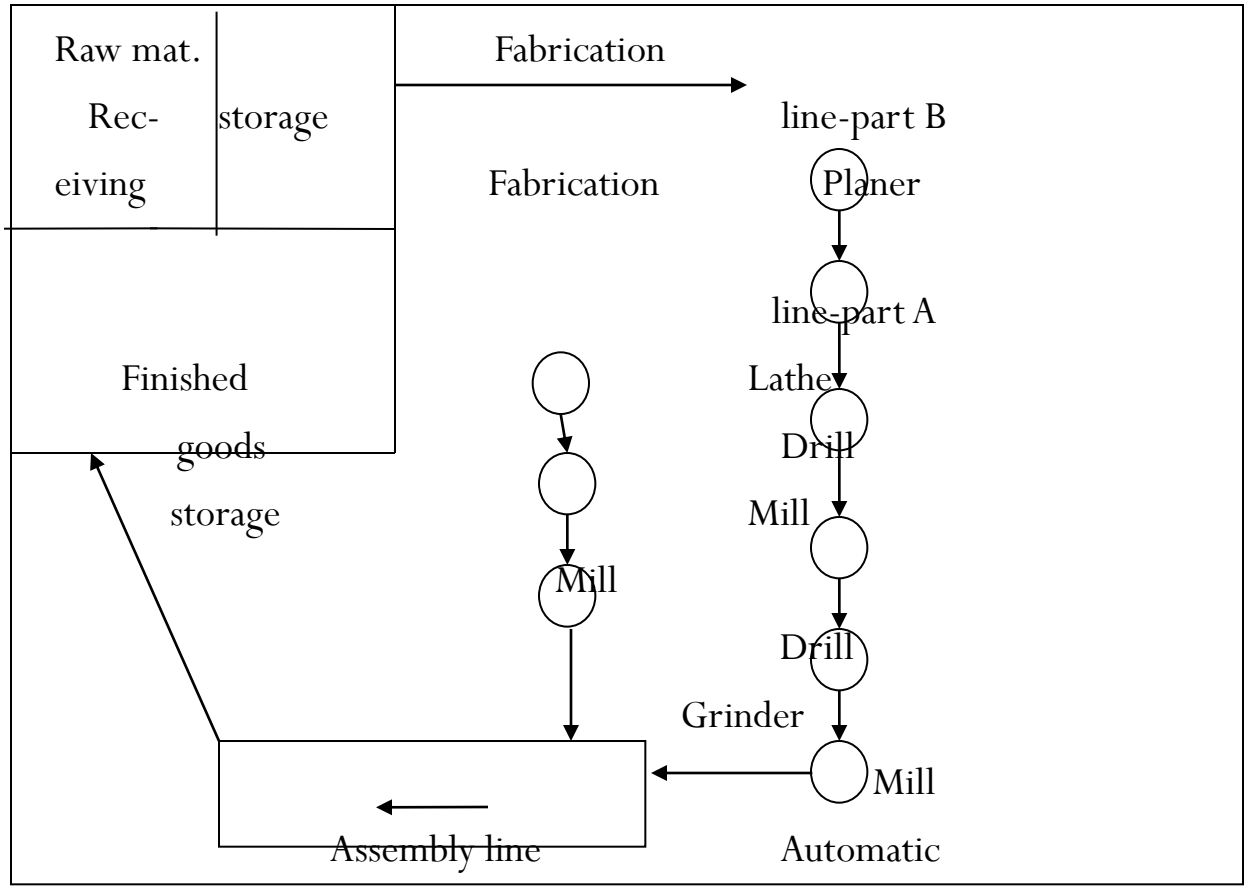
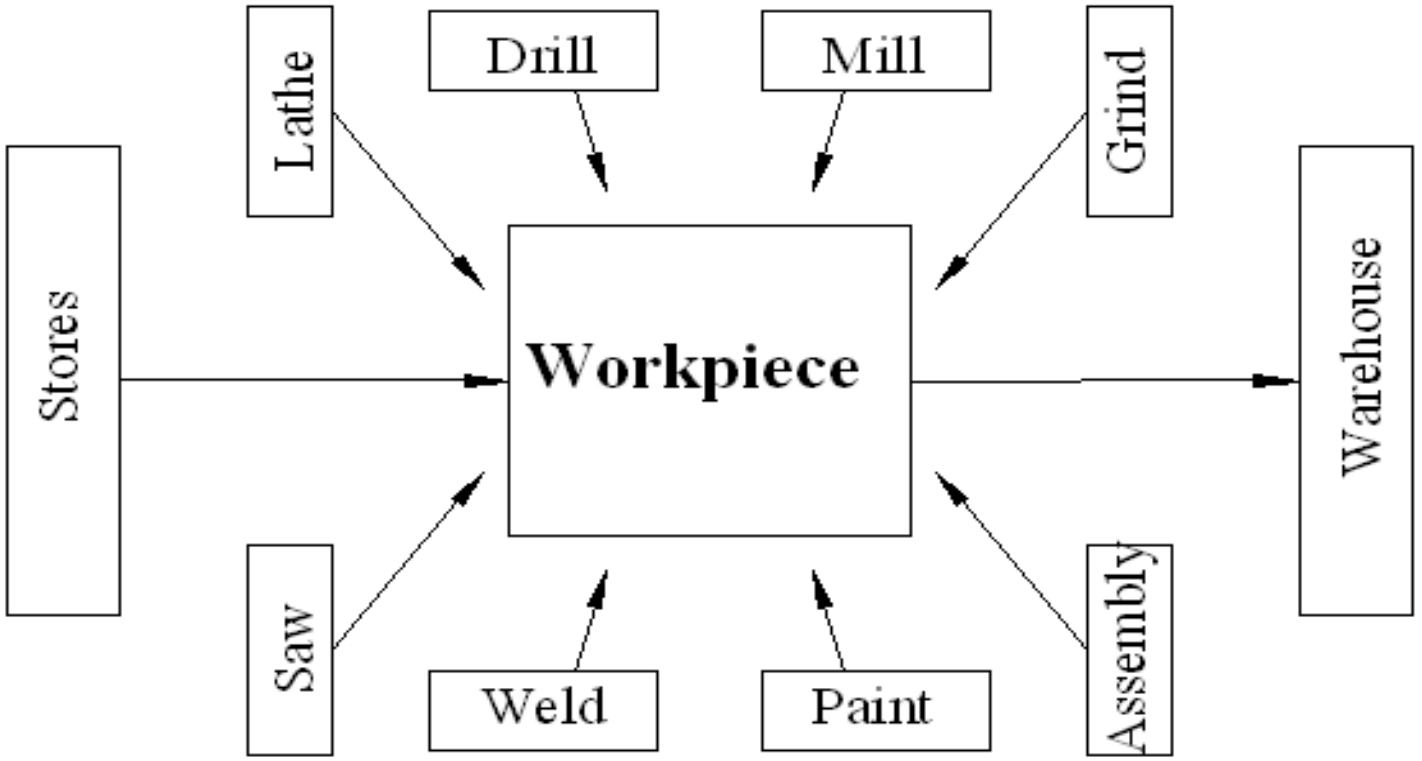



Small number of high volume products

# ii. Static or Fixed Position Layout



# 5. Group technology layout

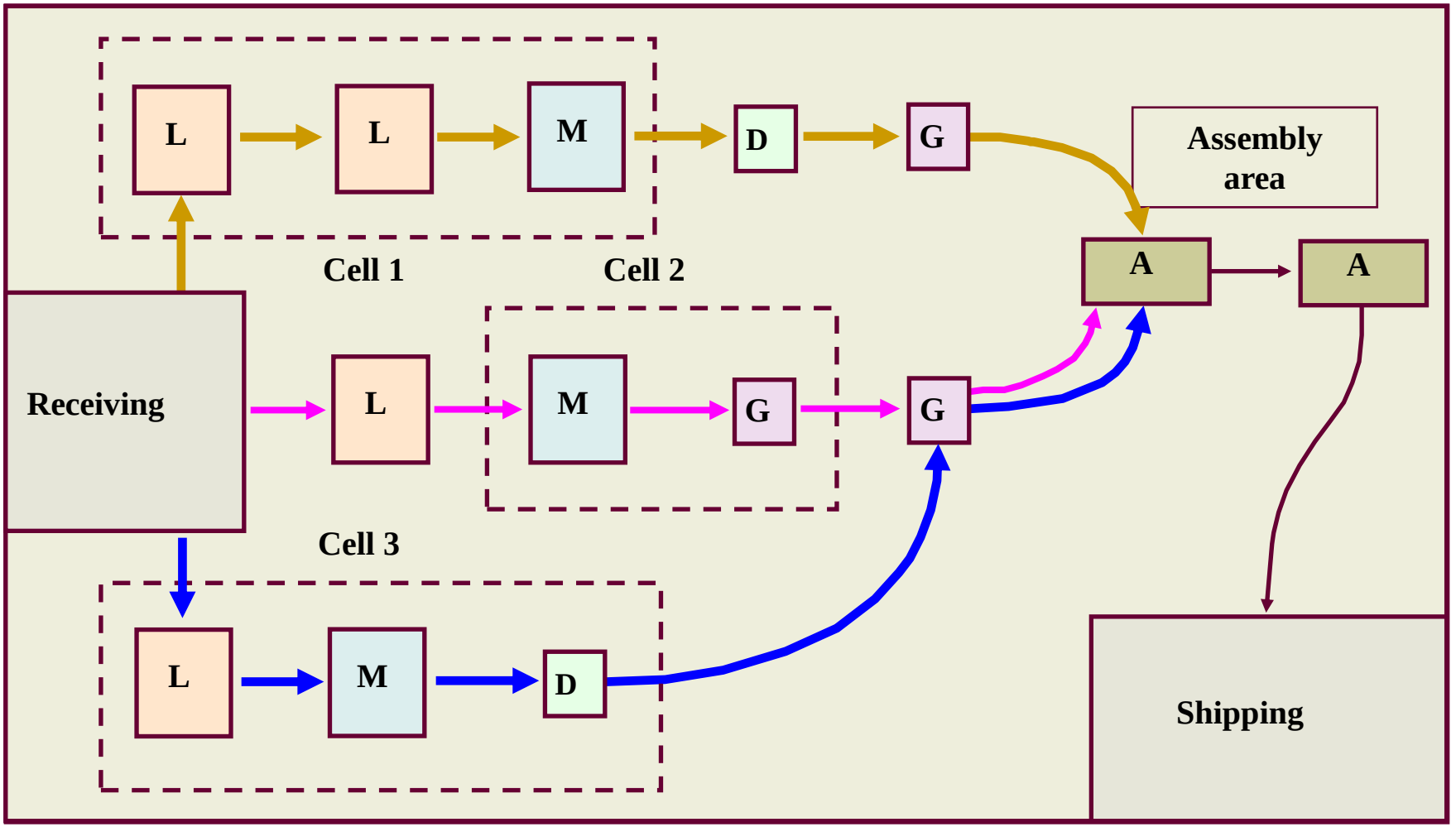
- Production volumes for individual products are not sufficient to justify product layouts.
- Grouping products into logical product families, a product layout can be justified for the family.

- “Group technology is the technique of identifying and bringing together related or similar parts in a production process in order to utilize the inherent economy of flow production methods.”
- Group Technology layout is also called manufacturing cell layout.

Example:

- A plant producing 10,000 part numbers may be able to group the parts into 50 or 60 families. Each family would possess similar design and manufacturing characteristics.
- Hence, the processing of each member of a given family would be similar, and this results in manufacturing efficiencies in the form of:
  - Reduced set-up,
  - Lower in-process inventories,
  - Better scheduling,
  - Improved tool control,
  - Standard process plan.

# Group Technology



## Common reasons for the design of layouts

- ✓ Changes in design of products/services
- ✓ Introduction of new products/services
- ✓ Market demand change
- ✓ Changes in technology/equipment
- ✓ Poor worker environment
- ✓ Market relocation
- ✓ Cost reduction

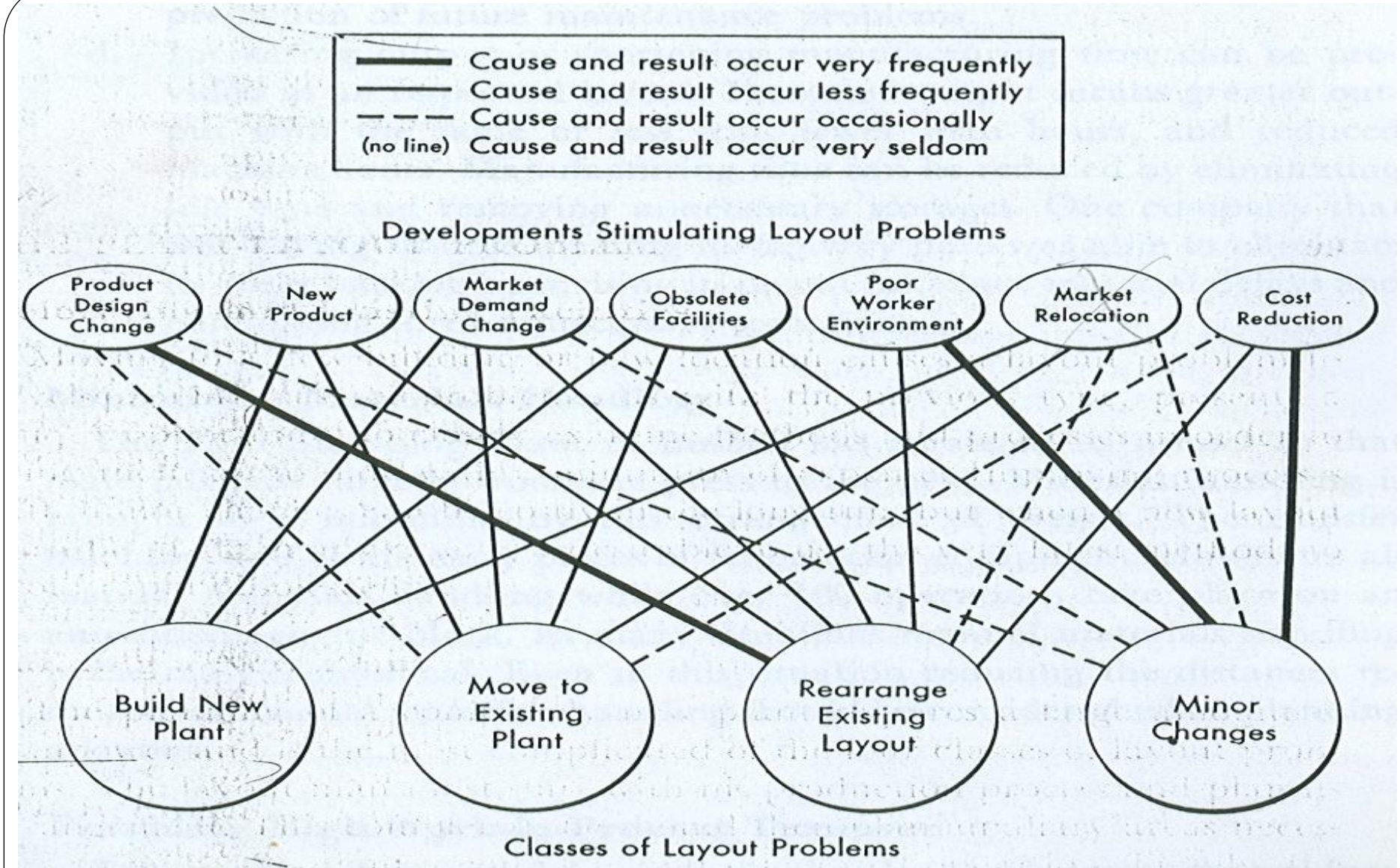



**Figure 5.1.** Graphical correlation between the development stimulating layouts and the classes of plant layout problems that result.

# Ergonomics and Industrial Safety

- Ergonomics is the study of the man in relation to his work
- Sometimes it is called by the name ‘human engineering or human factors engineering”
- “The application of human biological sciences along with engineering sciences to achieve optimum mutual adjustment of men and his work.
- The benefits being measured in terms of human efficiency and well-being.”

# Objectives of human engineering

Human engineering (ergonomics) has two broad objectives:

I. To enhance the efficiency and effectiveness with which the activity (work) is carried out so as to increase the convenience of use, reduced errors and increase in productivity.

II. To enhance certain desirable human values including safety reduced stress and fatigue and improved quality of life.

- Ergonomics aims at providing comfort and improved working conditions so as to channelize the energy, skills of the workers into constructive & productive work.
- This accounts for increased productivity, safety and reduces the fatigue.

# Thank you!!!