Computer Integrated Manufacturing (CIM)

Basics of Manufacturing Systems

Dr. Mirza Jahanzaib

Overview of Manufacturing

1. Manufacturing Operations
2. Manufacturing Models (mathematical)

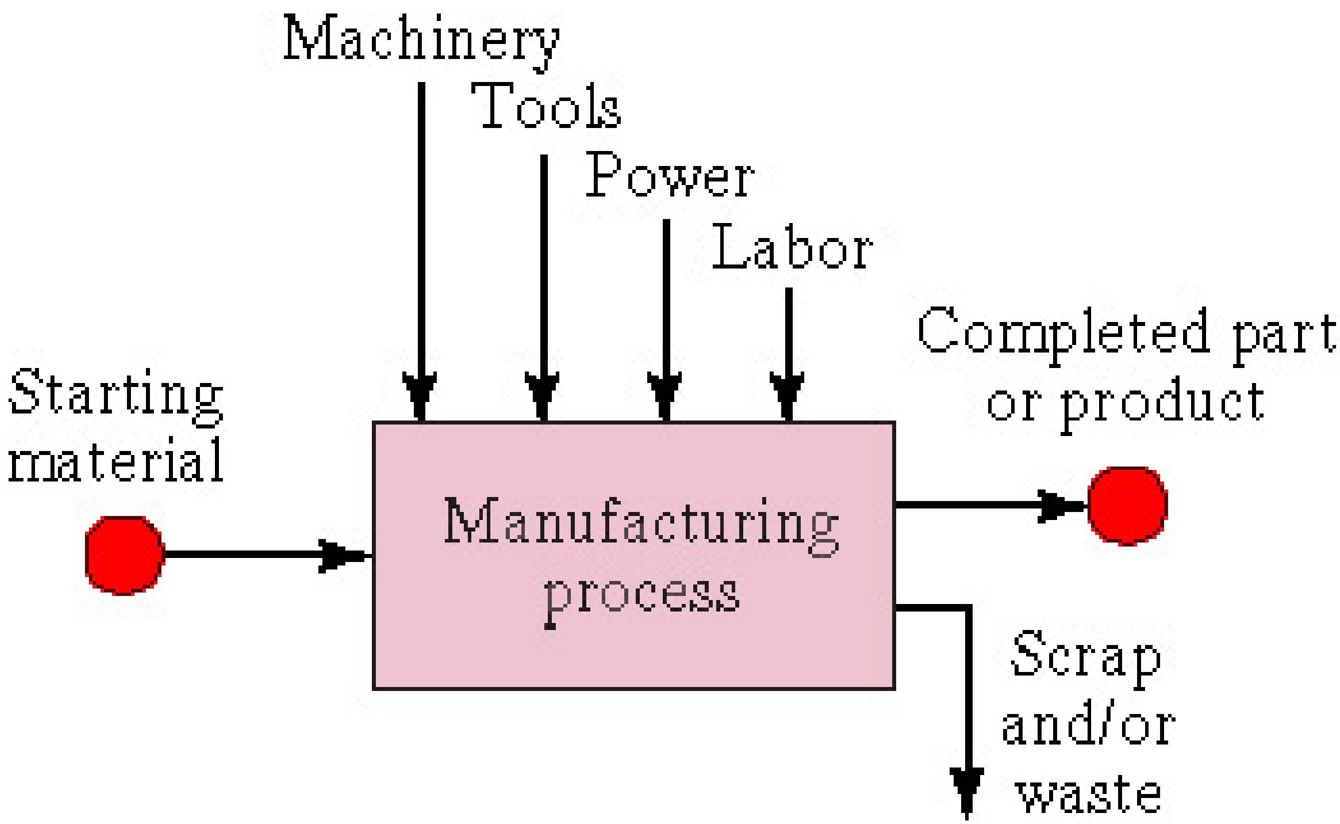
1. Manufacturing Operations

1. Manufacturing Industries and Products
2. Manufacturing Operations
3. Production Facilities
4. Product/Production Relationships

Definition (Technological)

Application of physical and chemical processes to alter the geometry, properties, and/or appearance of a given starting material to make parts or products

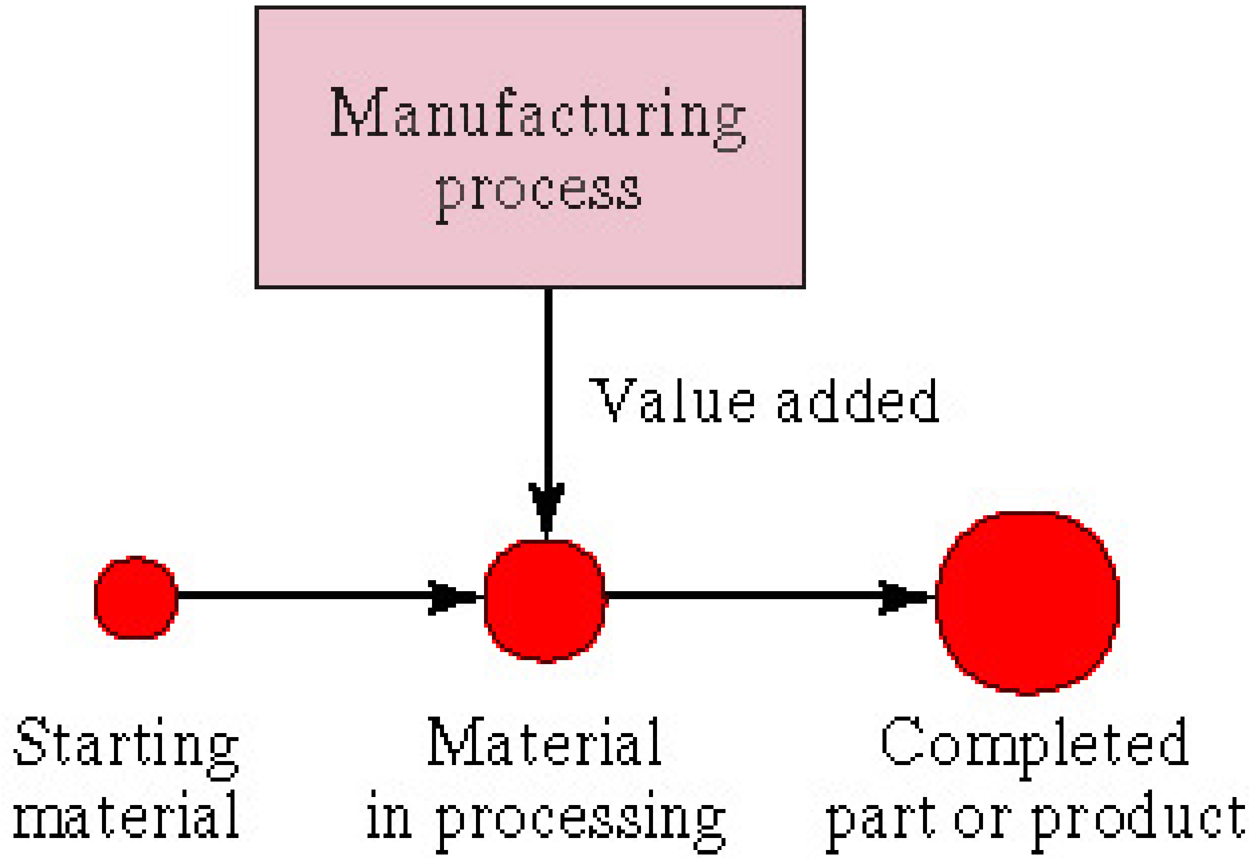
- Manufacturing also includes the joining of multiple parts to make assembled products


Machinery
Tools
Power
Labor
Starting material
Manufacturing process
Completed part or product
Scrap and/or waste

Definition (Economic)

Transformation of materials into items of greater value by means of one or more processing and/or assembly operations

- Manufacturing ***adds*** *value* to the material
  - Converting **iron ore** to **steel** adds value
  - Refining **petroleum** into **plastic** adds value


Manufacturing process
Value added
Starting material
Material in processing
Completed part or product

Classification of Industries

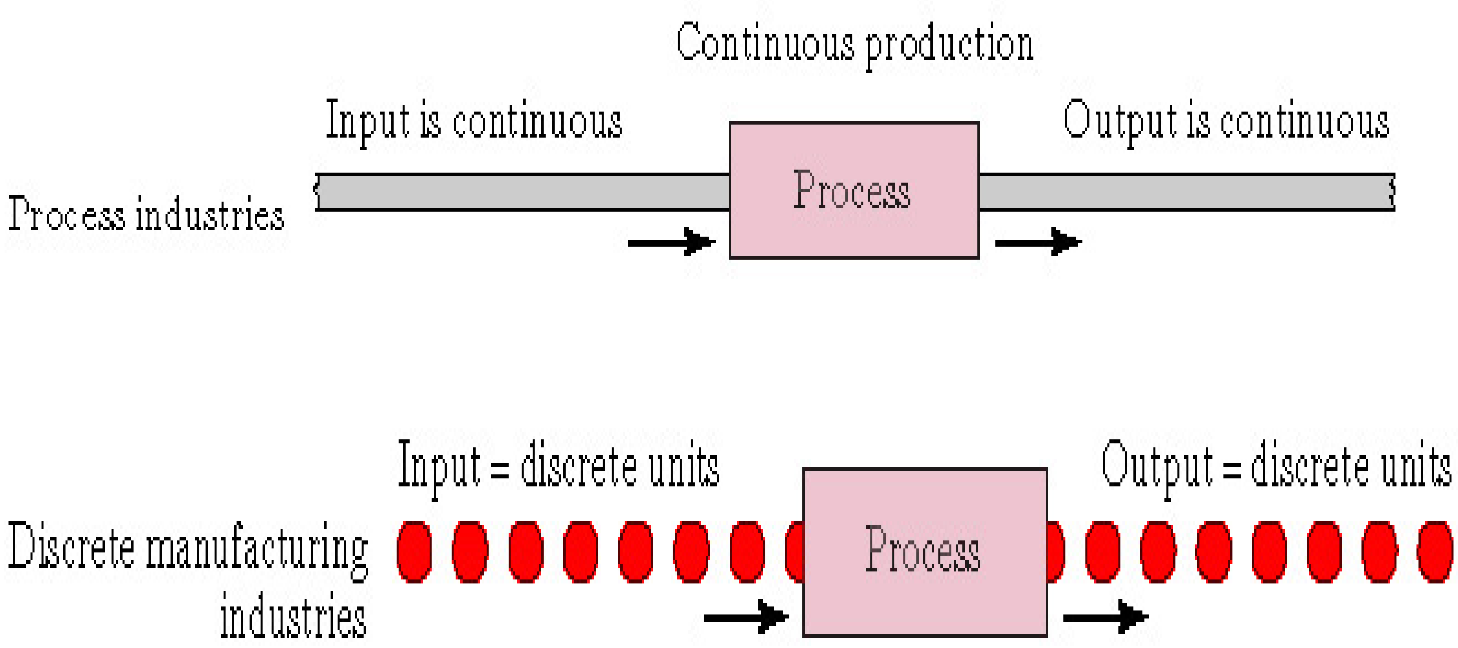
1. Primary industries – cultivate and exploit natural resources
   - Examples: agriculture, mining
2. Secondary industries – convert output of primary industries into products
   - Examples: manufacturing, power generation, construction
3. Tertiary industries – service sector
   - Examples: banking, education, government, legal services, retail trade, transportation

Manufacturing Industries Classifications

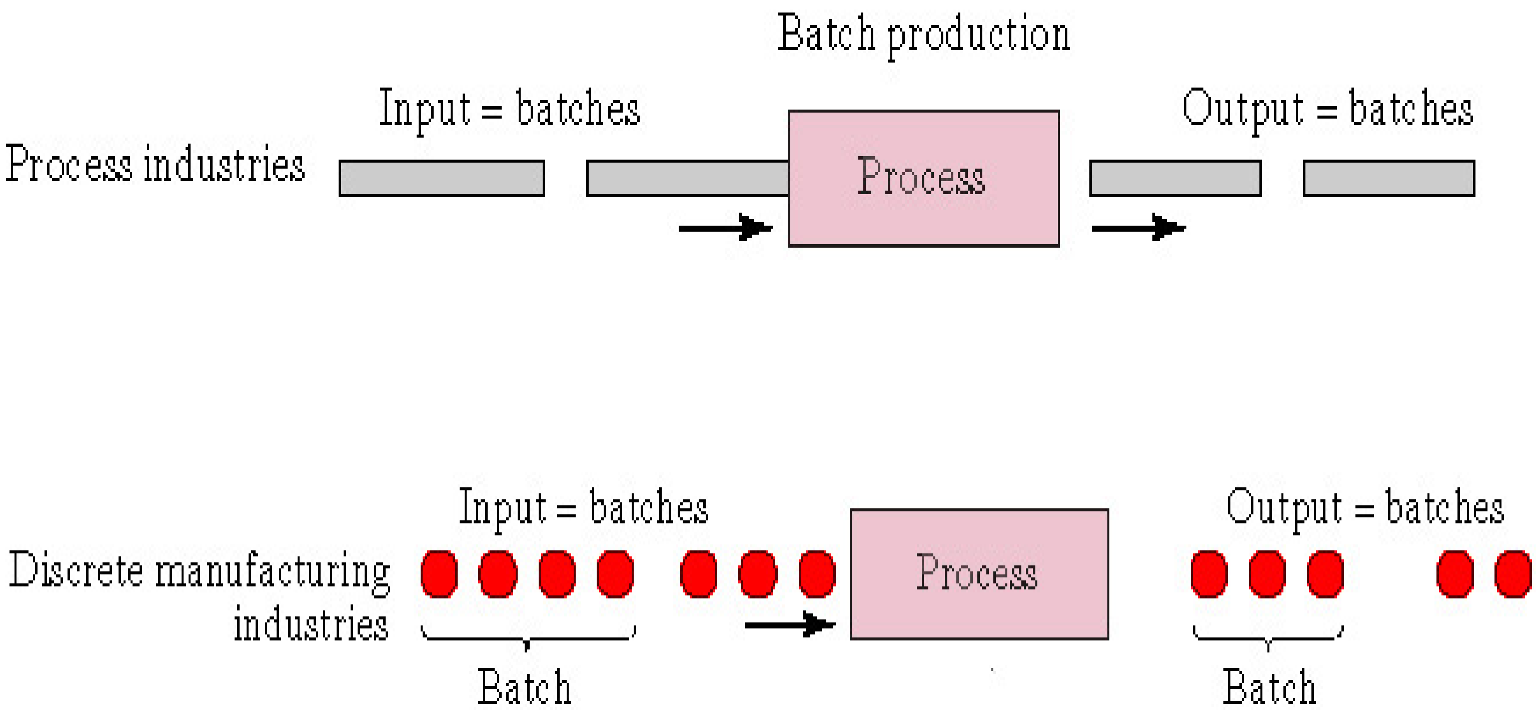
- **Process industries**, e.g., chemicals, petroleum, basic metals, foods and beverages, power generation
  - Continuous production
  - Batch production
- **Discrete product** (and part) industries, e.g., cars, aircraft, appliances, machinery, and their component parts
  - Continuous production
  - Batch production

Process & Discrete Parts

<u>Continuous Production</u>



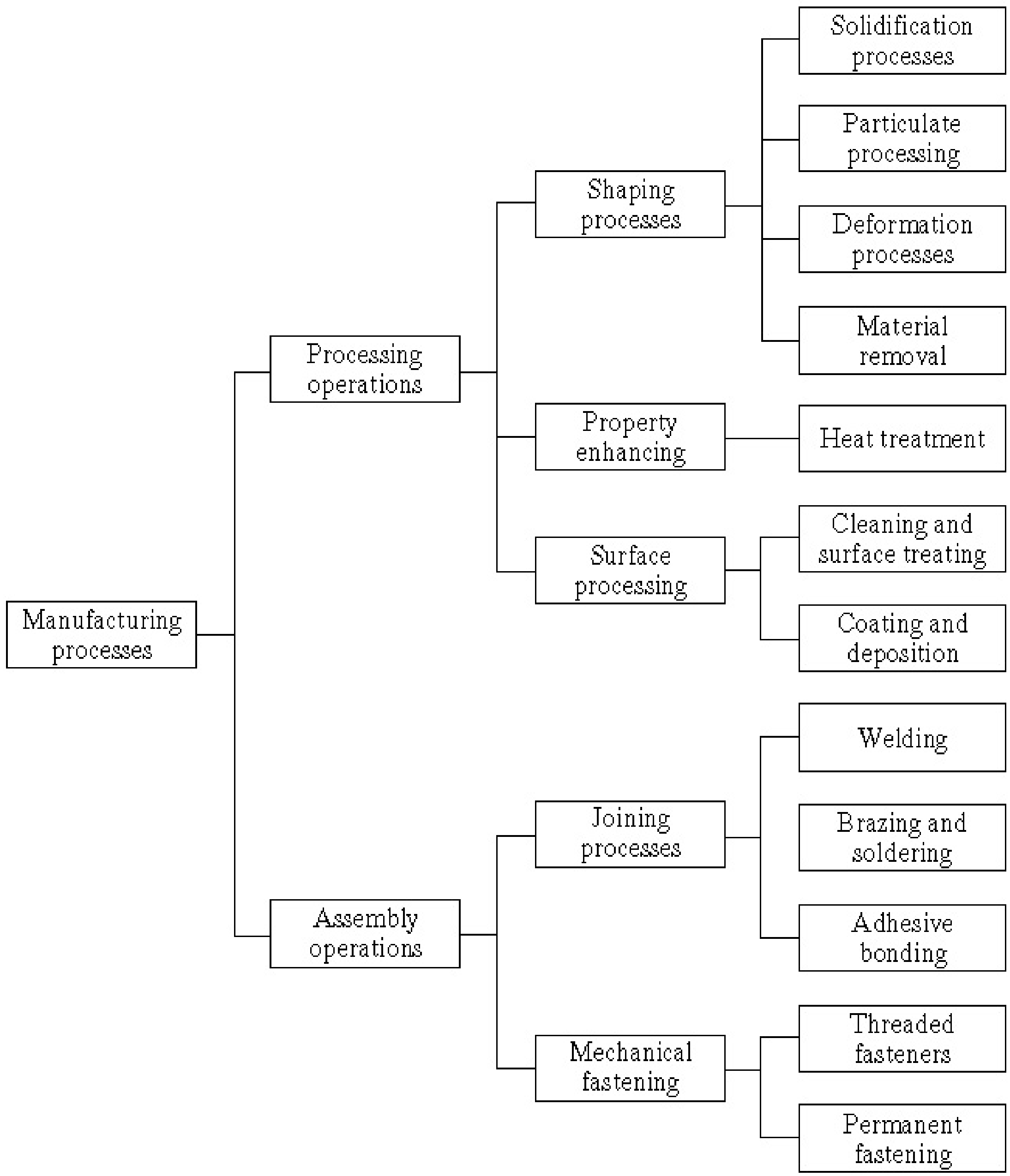
Batch Production



Manufacturing Operations

- There are certain basic activities that must be carried out in a factory to convert raw materials into finished products
- For discrete products:
  1. Processing and assembly operations
  2. Material handling
  3. Inspection and testing
  4. Coordination and control

Classification of Manufacturing Process



Processing Operations

- **Shaping operations**
  1. Solidification processes
  2. Particulate processing
  3. Deformation processes
  4. Material removal processes
- **Property-enhancing operations** (heat treatments)
- **Surface processing operations**
  - Cleaning and surface treatments
  - Coating and thin-film deposition

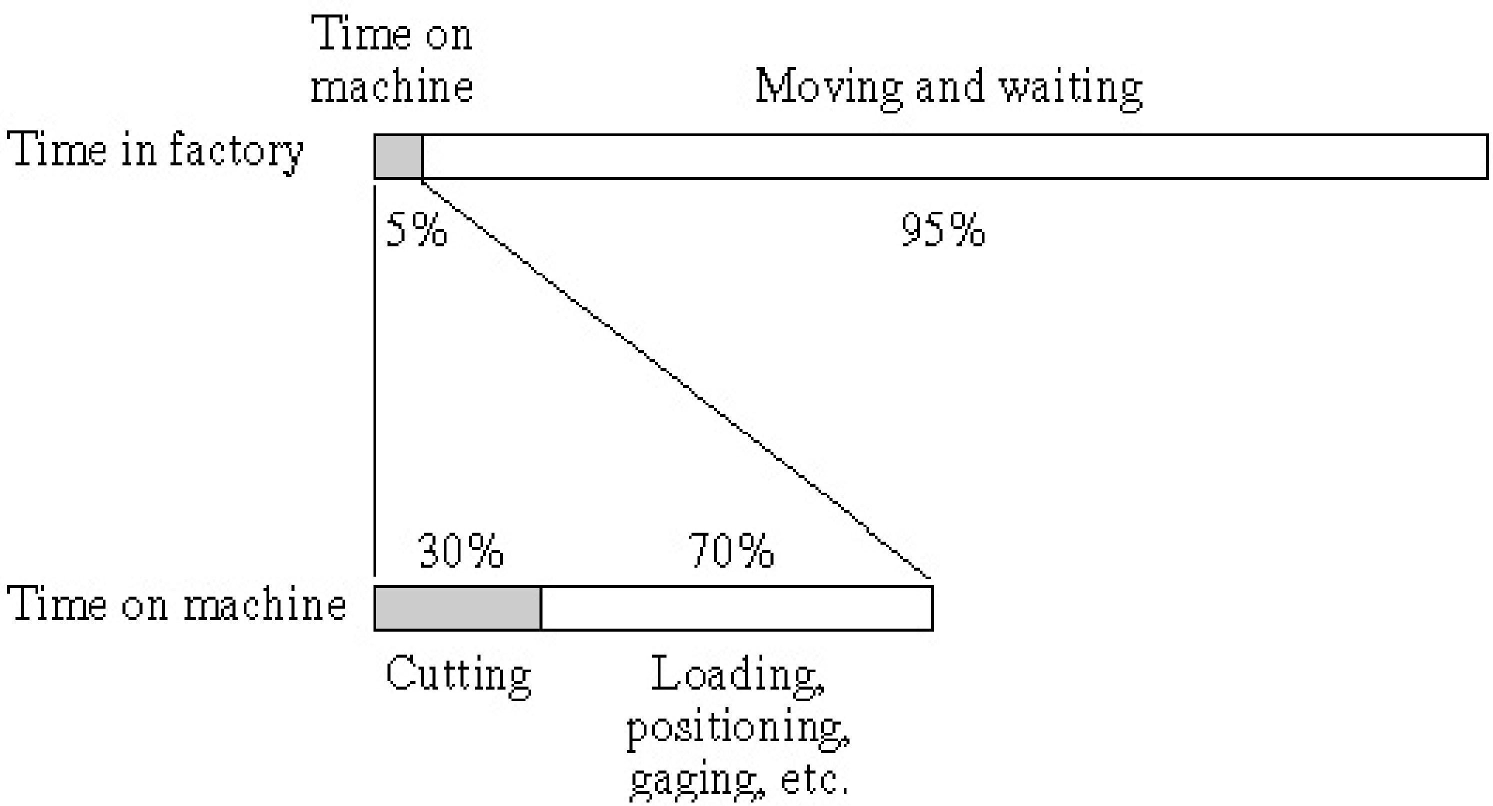
Assembling Operations

- **Joining processes**
  - Welding
  - Brazing and soldering
  - Adhesive bonding
- **Mechanical assembly**
  - Threaded fasteners (e.g., bolts and nuts, screws)
  - Rivets
  - Interference fits (e.g., press fitting, shrink fits)
  - Other

Material Handling

- **Material transport**
  - Vehicles, e.g., forklift trucks, AGVs, monorails
  - Conveyors
  - Hoists and cranes
- **Storage systems**
- **Unitizing equipment**
- **Automatic identification** and data capture
  - Bar codes
  - RFID

Time Spent in Material Handling



Inspection & Testing

Inspection – examination of the product and its components to determine whether they conform to design specifications

- Inspection for variables - measuring
- Inspection of attributes – gaging

Testing – observing the product (or part, material, subassembly) during actual operation or under conditions that might occur during operation

Coordination & Control

- Regulation of the individual processing and assembly operations
  - Process control
  - Quality control
- Management of plant level activities
  - Production planning and control
  - Quality control

Production Facilities

- A manufacturing company attempts to organize its facilities in the most efficient way to serve the particular mission of the plant
- Certain types of plants are recognized as the most appropriate way to organize for a given type of manufacturing
- The most appropriate type depends on:
  - Types of products made
  - Production quantity
  - Product variety

Production Quantity

Number of units of a given part or product produced annually by the plant

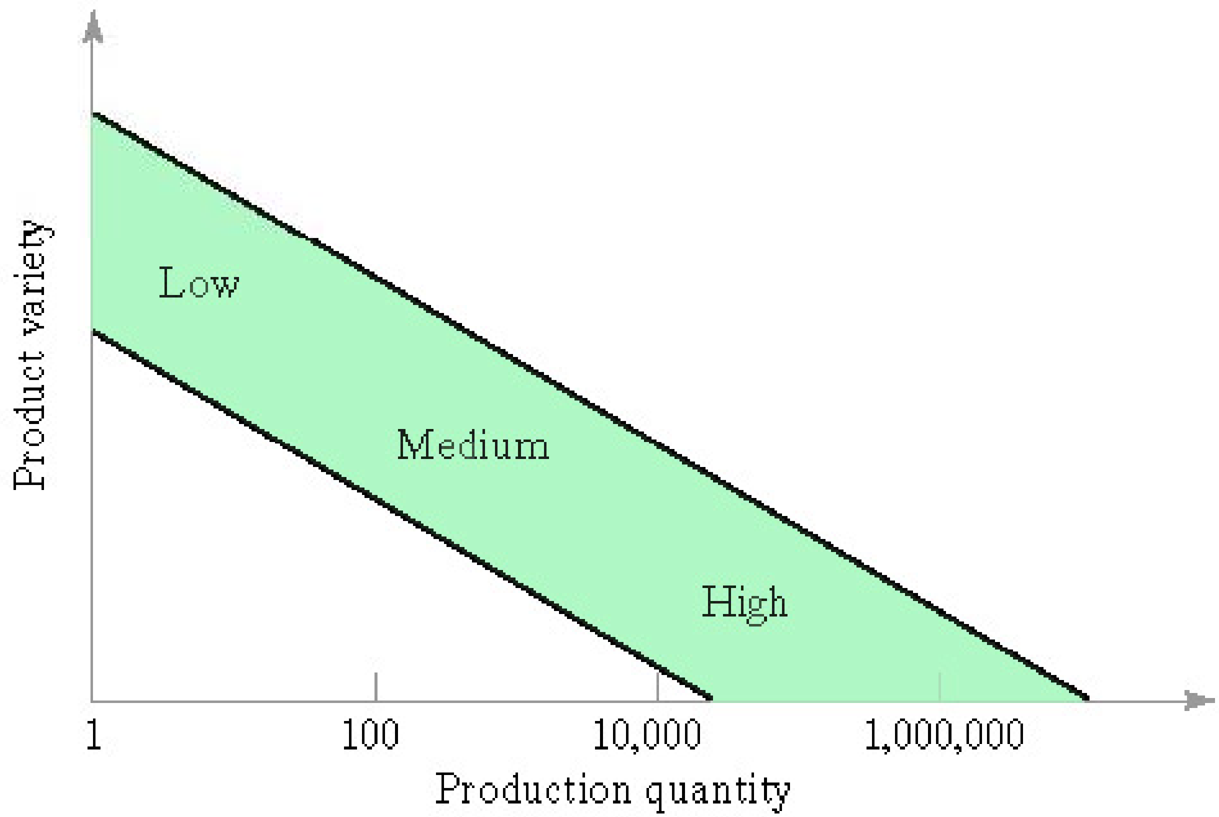
- Three quantity ranges:
  1. Low production – 1 to 100 units
  2. Medium production – 100 to 10,000 units
  3. High production – 10,000 to millions of units

Product Variety

Refers to the number of different product or part designs or types produced in the plant

- Inverse relationship between production quantity and product variety in factory operations
  - Hard product variety – products differ greatly
    - Few common components in an assembly
  - Soft product variety – small differences between products

Relationship b/w Production Quantity & Product Variety

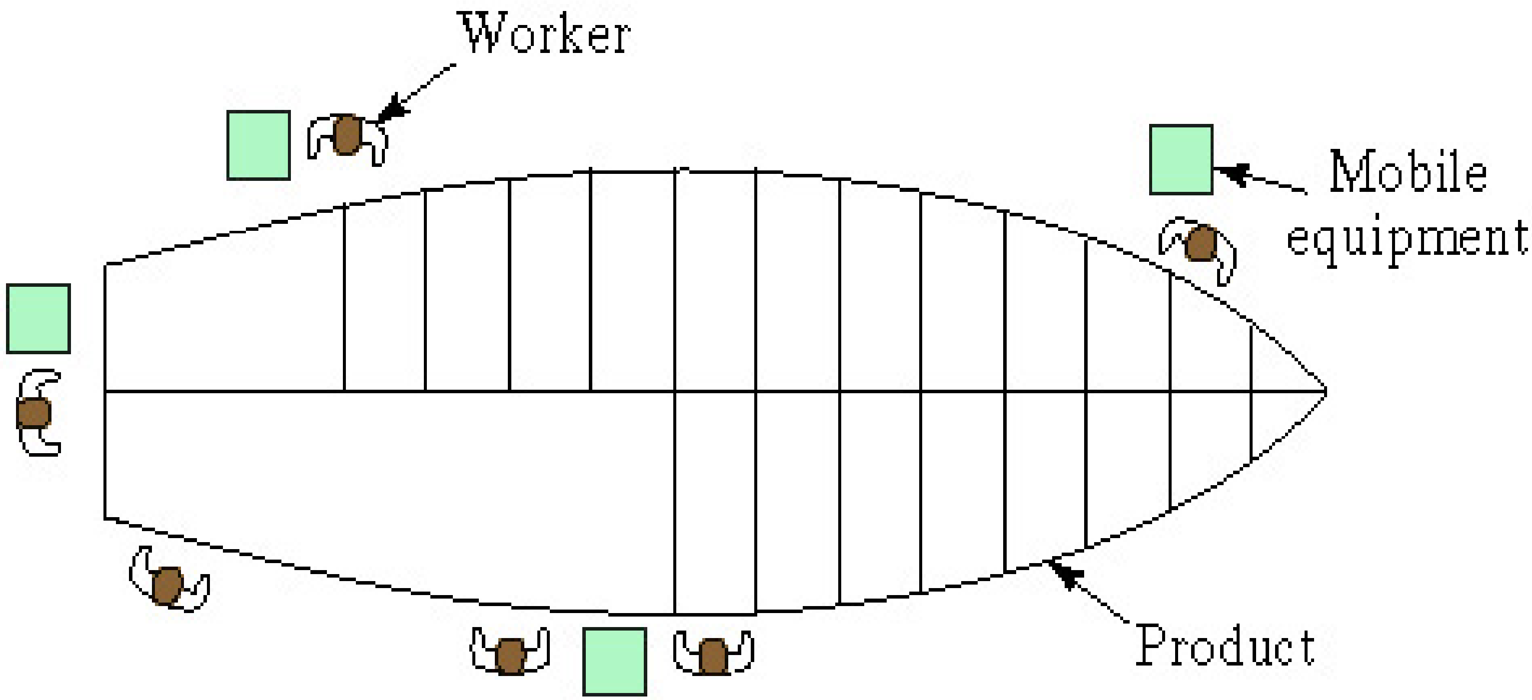


Low Production Quantity

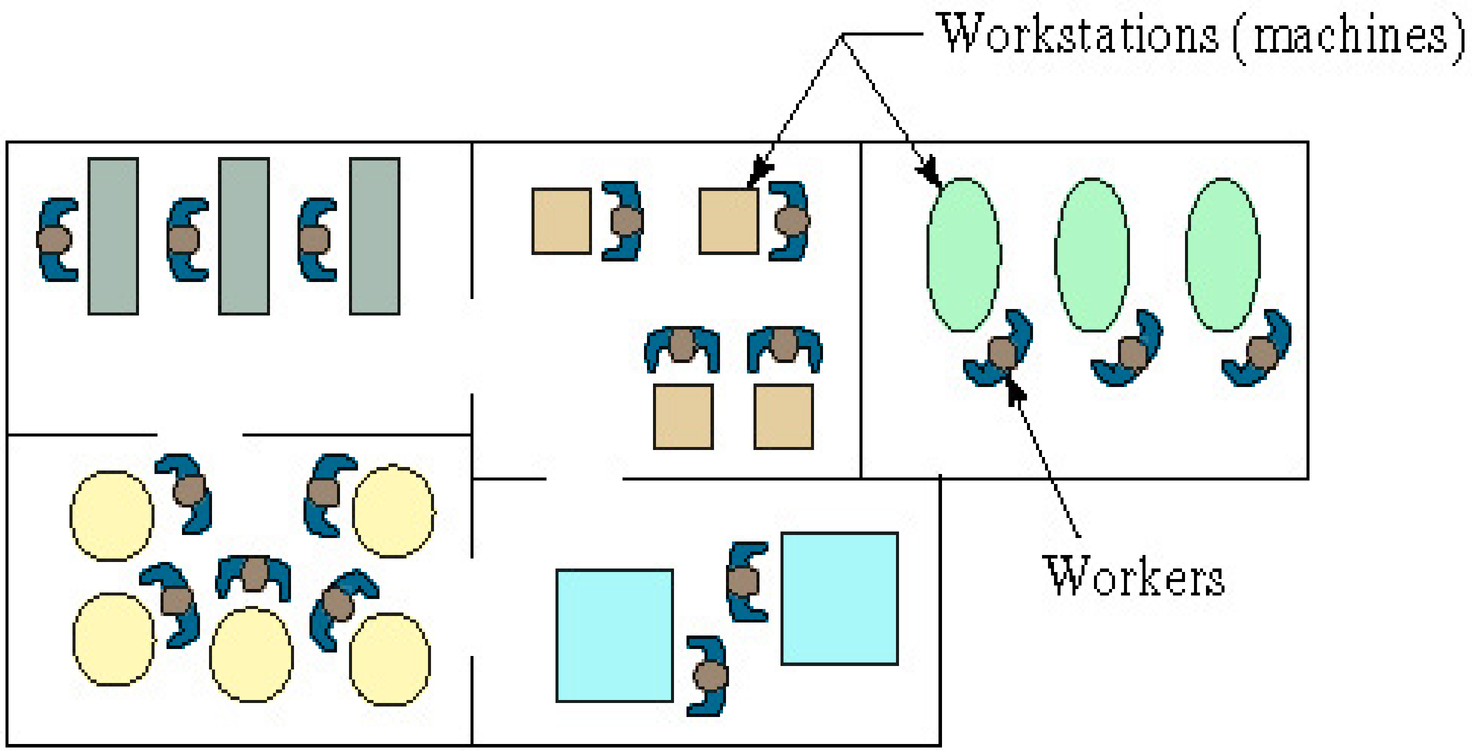
Job shop – makes low quantities of **specialized and customized products**

- Products are typically complex (e.g., specialized machinery, prototypes, space capsules)
- Equipment is **general** purpose
- Plant layouts:
  - Fixed position
  - Process layout

Fixed Position Layout



Process Layout

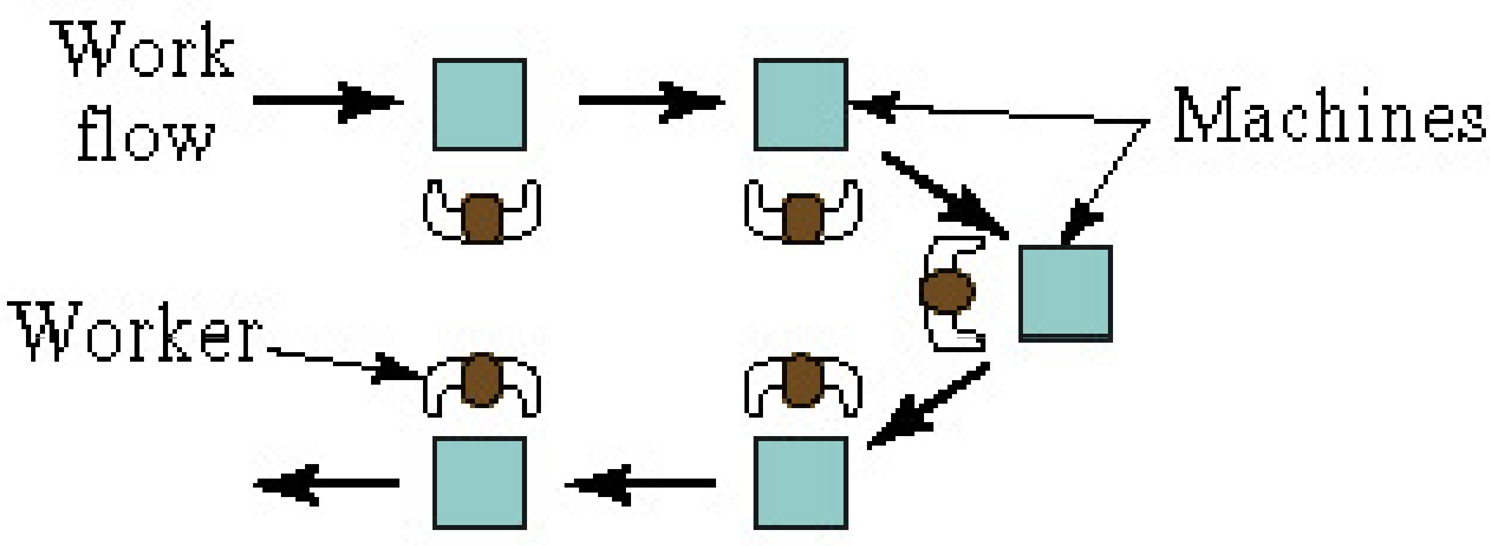


Medium Production Quantities

1. **Batch production** – A batch of a given product is produced, and then the facility is changed over to produce another product
   - Changeover takes time – **setup time**
   - Typical layout – **process layout**
   - Hard product variety

2. **Cellular Manufacturing** – A mixture of products is made without significant changeover time between products
   - Typical layout – **cellular layout**
   - Soft product variety

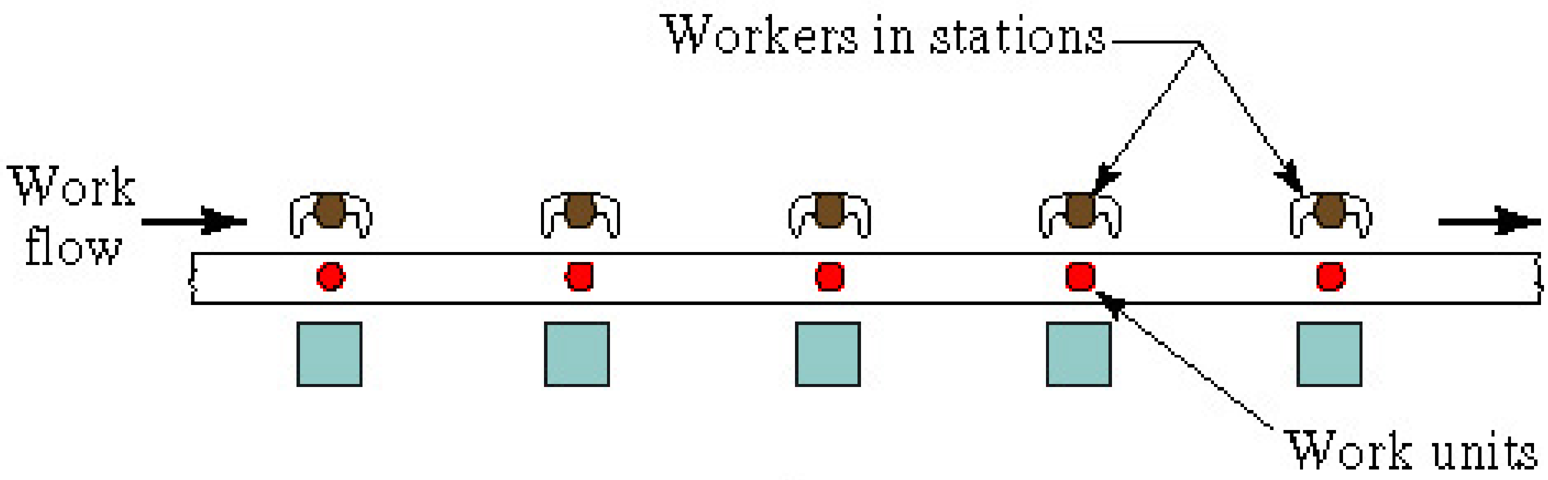
Cellular Layout



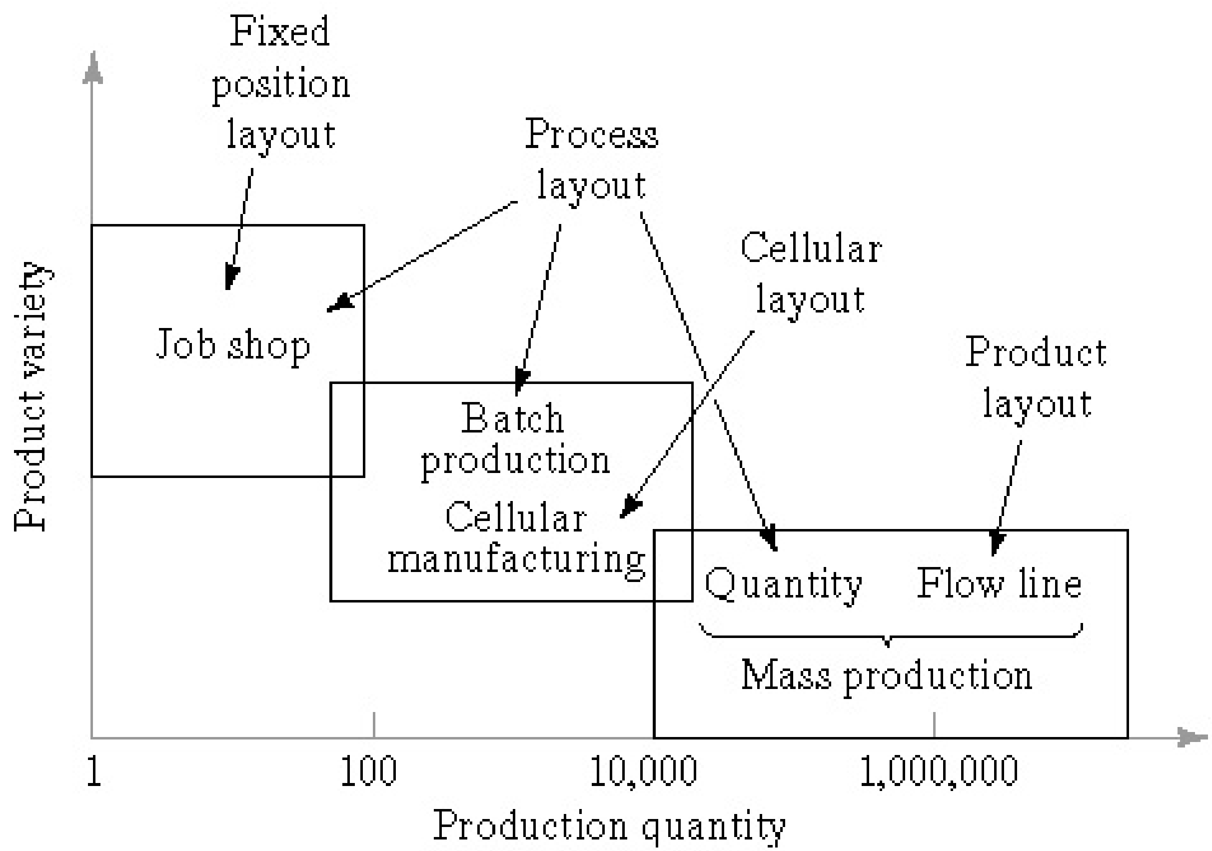
High Production

1. **Quantity production** – Equipment is dedicated to the manufacture of one product
   - Standard machines tooled for high production (e.g., stamping presses, molding machines)
   - Typical layout – **process layout**
2. **Flow line production** – Multiple workstations arranged in **sequence**
   - Product requires multiple processing or assembly steps
   - Product layout is most common

Product Layout



Relationship b/w Plant layout and Type of Facility



Product/Production Relationship

- Total number of product units = $Q_f = \sum_{j=1}^{P} Q_j$
- Product variety
  - Hard product variety = **differences between products**
  - Soft product variety = **differences between models of products**
- Product and part complexity
  - Product complexity n_p = number of parts in product
  - Part complexity n_o = number of operations per part

Factory Operations Models

Simplified for purposes of conceptualization:

- Total number of product units $Q_f = PQ$

- Total number of parts produced

$$n_{pf} = PQn_p$$

- Total number of operations $n_{of} = PQn_pn_o$

Limitations and Capabilities of Manufacturing Plants

Manufacturing capability - the technical and physical limitations of a manufacturing firm and each of its plants

- Three dimensions of manufacturing **capability**:
  1. **Technological processing capability** - the available set of manufacturing processes
  2. **Physical size and weight** of product
  3. **Production capacity** (plant capacity) - production quantity that can be made in a given time

2. Manufacturing Models (Mathematical) and Metrics

Models Include

1. Mathematical Models of Production Performance
2. Manufacturing Costs

Production Concepts and Mathematical Models

- Production rate R_p
- Production capacity *PC*
- Utilization *U*
- Availability *A*
- Manufacturing lead time *MLT*
- Work-in-progress *WIP*

Operation Cycle Time

Typical **cycle time** for a production operation:

$$T_c = T_o + T_h + T_{th}$$

where T_c = cycle time, T_o = processing time for the operation, T_h = handling time (e.g., loading and unloading the production machine), and T_{th} = tool handling time (e.g., time to change tools)

Production Rate

Batch production: batch time $T_b = T_{su} + QT_c$

Average production time per work unit $T_p = T_b/Q$

Production rate $R_p = 1/T_p$

Job shop production:

For $Q = 1$, $T_p = T_{su} + T_c$

For **quantity high production**:

$R_p = R_c = 60/T_p$ since $T_{su}/Q \rightarrow 0$

For flow line production

$T_c = T_r + \text{Max } T_o$ and $R_c = 60/T_c$

Production Capacity

Plant capacity for facility in which parts are made in one operation ($n_o = 1$):

$$PC_w = n\, S_w\, H_s\, R_p$$

where PC_w = weekly plant capacity, units/wk

Plant capacity for facility in which parts require multiple operations ($n_o > 1$):

$$PC_w = \frac{n S_w H_s R_p}{n_o}$$

where n_o = number of operations in the routing

Utilization & Availability

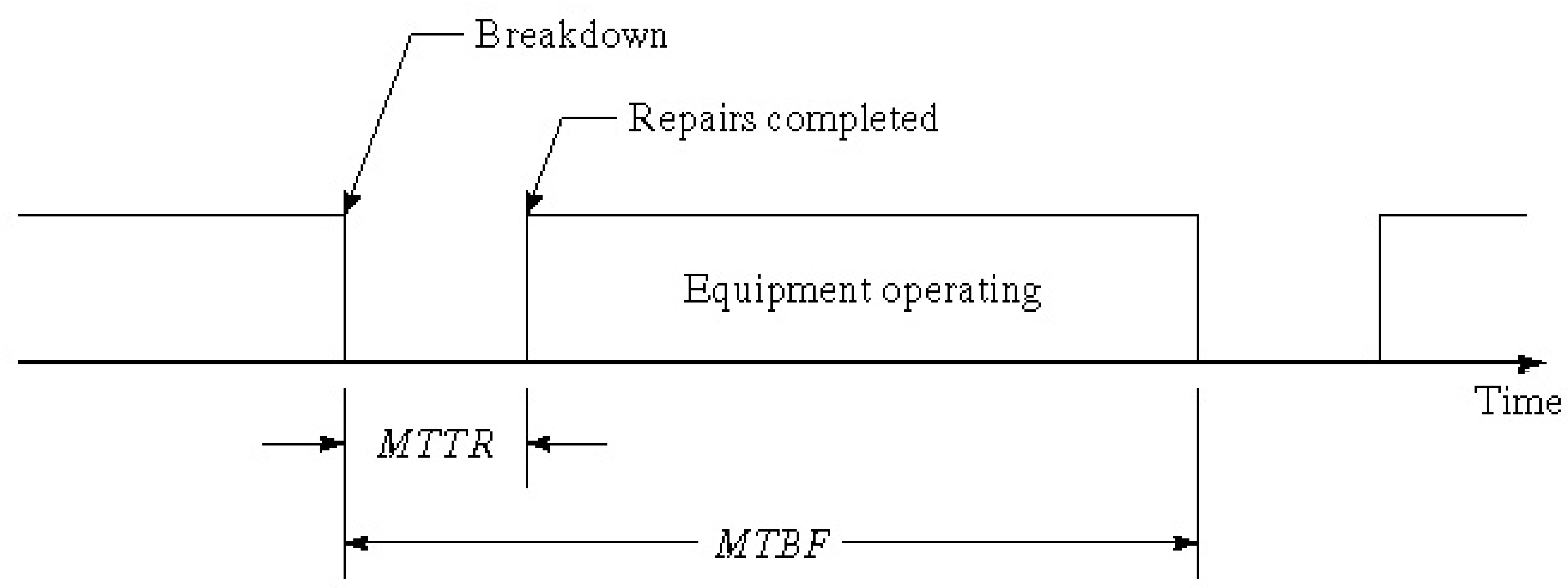
Utilization: $U = \frac{Q}{PC}$

where Q = quantity actually produced, and PC = plant capacity

Availability: $A = \frac{MTBF - MTTR}{MTBF}$

where $MTBF$ = mean time between failures, and $MTTR$ = mean time to repair

Availability - MTBF and MTTR Defined



Manufacturing Lead Time

$$MLT = n_o\,(T_{su} + QT_c + T_{no})$$

where MLT = manufacturing lead time, n_o = number of operations, T_{su} = setup time, Q = batch quantity, T_c cycle time per part, and T_{no} = non-operation time

Work In Process

$$WIP = \frac{AU(PC)(MLT)}{S_w H_{sh}}$$

where WIP = work-in-process, pc; A = availability, U = utilization, PC = plant capacity, pc/wk; MLT = manufacturing lead time, hr; S_w = shifts per week, H_{sh} = hours per shift, hr/shift

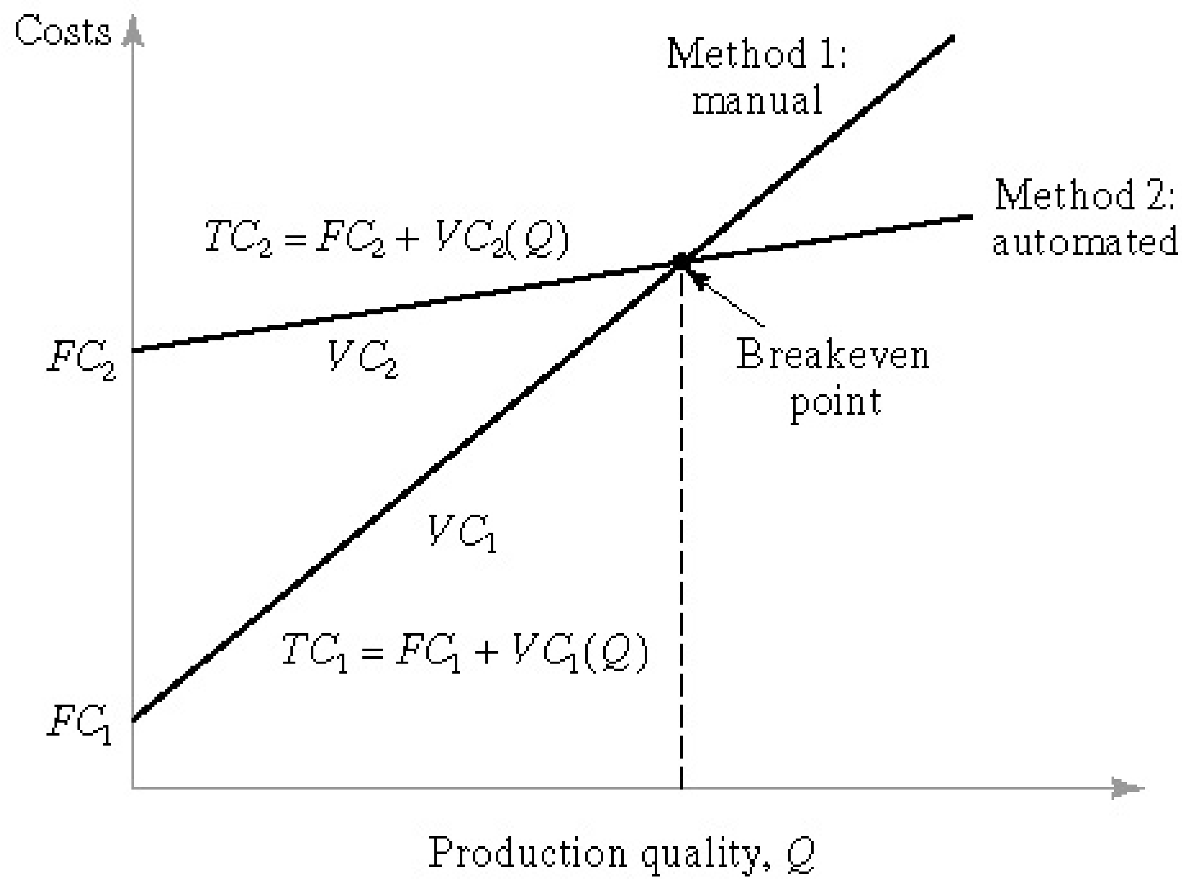
Costs of Manufacturing Operations

- Two major categories of manufacturing costs:
  1. **Fixed costs** - remain constant for any output level
  2. **Variable costs** - vary in proportion to production output level
- Adding fixed and variable costs

$$TC = FC + VC\,(Q)$$

where TC = total costs, FC = fixed costs (e.g., building, equipment, taxes), VC = variable costs (e.g., labor, materials, utilities), Q = output level.

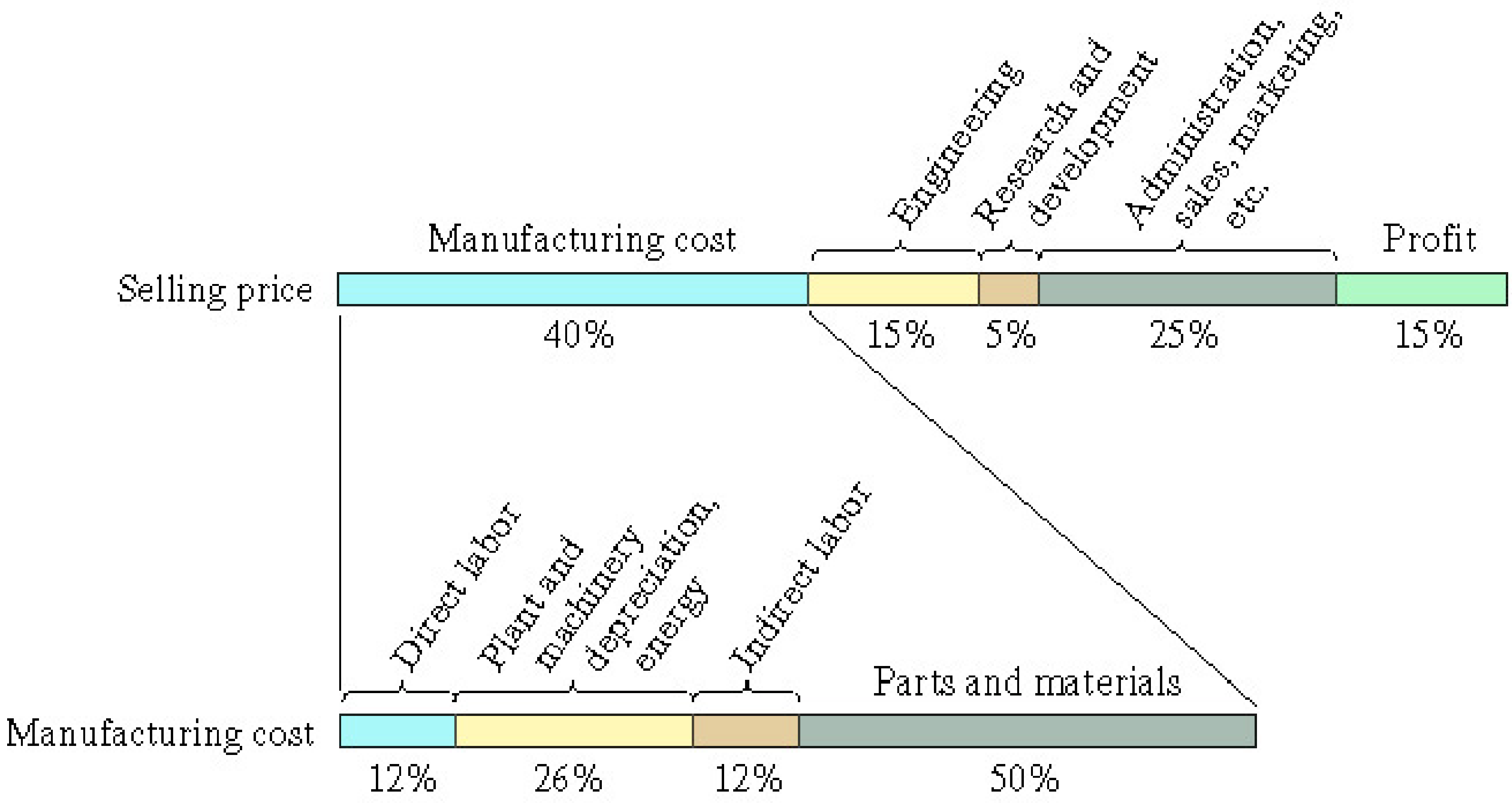
Fixed & Variable Costs



Manufacturing Costs

- Alternative classification of manufacturing costs:
  1. **Direct labor** - wages and benefits paid to workers
  2. **Materials** - costs of raw materials
  3. **Overhead** - all of the other expenses associated with running the manufacturing firm
     - Factory overhead
     - Corporate overhead

Typical manufacturing Cost



Factory Overheads

Factory overhead rate:

$$FOHR = \frac{FOHC}{DLC}$$

Corporate overhead rate:

$$COHR = \frac{COHC}{DLC}$$

where *DLC* = direct labor costs

Cost of Equipment Usage

Hourly cost of worker-machine system:

$$C_o = C_L(1 + FOHR_L) + C_m(1 + FOHR_m)$$

where C_o = hourly rate, \$/hr; C_L = labor rate, \$/hr; $FOHR_L$ = labor factory overhead rate, C_m = machine rate, \$/hr; $FOHR_m$ = machine factory overhead rate

Problem 1

- The ABC Company is planning a new product line and will build a new plant to manufacture the parts for a new product line. The product line will include 50 different models. Annual production of each model is expected to be 1000 units. Each product will be assembled of 400 components. All processing of parts will be accomplished in one factory. There are an average of 6 processing steps required to produce each component, and each processing step takes 1.0 minute (includes an allowance for setup time and part handling). All processing operations are performed at workstations, each of which includes a production machine and a human worker. If each workstation requires a floor space of 250 ft^2, and the factory operates one shift (2000 hr/yr), determine (a) how many production operations, (b) how much floor-space, and (c) how many workers will be required in the plant.

Solution

(a) $n_{of} = PQn_pn_o$ = 50(1000)(400)(6) = **120,000,000 operations** in the factory per year.

(c) Total operation time = (120 x 10^6 ops)(1min./(60 min./hr)) = 2,000,000 hr/yr.

At 2000 hours/yr per worker, $w = \frac{2{,}000{,}000 \text{hr / yr}}{2000 \text{hr / worker}}$

= **1000 workers**.

(b) Number of workstations $n = w$ = 1000. Total floor-space = (1000 stations)(250 ft^2/station) = **250,000 ft^2**

Problem 2

The average part produced in a certain batch manufacturing plant must be processed sequentially through six machines on average. Twenty (20) new batches of parts are launched each week. Average operation time = 6 min., average setup time = 5 hours, average batch size = 25 parts, and average non-operation time per batch = 10 hr/machine. There are 18 machines in the plant working in parallel. Each of the machines can be set up for any type of job processed in the plant. The plant operates an average of 70 production hours per week. Scrap rate is negligible.

Determine (a) manufacturing lead time for an average part,

(b) plant capacity, (c) plant utilization. (d) How would you expect the non-operation time to be affected by the plant utilization?

Solution

(a) $MLT = n_o (T_{su} + QT_c + T_{no})$

$MLT = 6(5 + 25(0.1) + 10) =$ **105 hr**

(b) $T_b = T_{su} + QT_c$

$T_p = (5 + 25 \times 0.1)/25 = 0.30$ hr/pc, $R_p = 3.333$ pc/hr.

$$PC_w = \frac{nS_wH_sR_p}{n_o}$$

$PC = 70(18)(3.333)/6 =$ **700 pc/week**

(c) Parts launched per week = 20 x 25 = 500 pc/week.

$$U = \frac{Q}{PC}$$

Utilization $U = 500/700 = 0.7143 =$ **71.43%**

(d) As utilization increases towards 100%, we would expect the non-operation time to increase. When the workload in the shop grows, the shop becomes busier, but it usually takes longer to get the jobs out. As utilization decreases, we would expect the non-operation time to decrease

Solve problems for better understanding of the basics of Manufacturing System

For specific problems TA will help