Manufacture is derived from two Latin words: manus (hand) and factus (make); the combination means “made by hand”.

• “Made by hand” accurately described the manual methods used when the English word “manufacture” was first coined in 1567.

• Today, modern manufacturing is accomplished by automated and computer-controlled machinery that is supervised manually.
Manufacturing (Technical)

Manufacturing is the 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 assembly of multiple parts to make products.

Manufacturing is almost always carried out as a sequence of operations: Manufacturing Processes.
Production briefly means to create utility or increase the value of economic goods.

The inputs required for production are,
1. Production objects (materials),
2. Production means,
   - Direct means (machine tools, power supplies, etc.)
   - Indirect means (roads, buildings, etc.)
3. Production labor,
4. Product information (knowledge), (know-how).
Fundamental Criteria that Determine Economical Production

1. Functional but simple design with an appropriate aesthetic quality,

2. A material choice that would best compromise between physical properties, appearance, cost, workability and machinability,

3. Proper selection of manufacturing process that would give no more accuracy or no better surface than necessary.
The quantity of products $Q$ made by a factory has an important influence on the way its people, facilities, and procedures are organized.

<table>
<thead>
<tr>
<th>Production range</th>
<th>Annual Quantity $Q$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low production</td>
<td>1 to 100 units</td>
</tr>
<tr>
<td>Medium production</td>
<td>100 to 10,000 units</td>
</tr>
<tr>
<td>High production</td>
<td>10,000 to millions of units</td>
</tr>
</tbody>
</table>
Product variety \( (P) \) refers to different product types produced in the plant.
• An inverse correlation exists between product variety $P$ and production quantity $Q$ in factory operations.

• If a factory's $P$ is high, then $Q$ is likely to be low; and if $Q$ is high, then $P$ is likely to be low.
Although $P$ is a quantitative parameter, it is much less exact than $Q$, because details on how much the designs differ is not captured simply by the number of different designs.

- **Soft product variety** - small differences between products, e.g., differences between car models made on the same production line, in which there is a high proportion of common parts among models.

- **Hard product variety** - products differ substantially, and there are few, if any, common parts, e.g., the difference between a small car and a large truck.
Manufacturing Systems

1. Job Shop Manufacturing
2. Flow Shop Manufacturing
3. Project Shop Manufacturing
4. Cellular Manufacturing System
5. Flexible Manufacturing System (FMS)

Based on Group Technology (GT) concept
1. Job Shop Manufacturing

- Designed for maximum flexibility.
- **General purpose equipment and machine tools** are used,
- Highly skilled labor is necessary,
- Thus wide variety of products can be produced.
- **For small (low) quantities** (1 to 100 units/year) more economical than others, but for large quantities not economical,
- Production usually depends on sales order.
- A job shop manufactures **low quantities of specialized and customized products**.
Typical Job (Machine) Shop
Job Shop Manufacturing

A transformation process in which units for different orders follow different paths through processes or machines. General purpose machines are grouped by function and adapted to the special requirements of different orders. As this kind of system grows to any size, the levels of cost and chaos increase.

The characteristics of this kind of production are,
- flexibility,
- wide variety of product design or customer service,
- need for many highly skilled people,
- much indirect labor,
- a great deal of manual material handling.
Job Shop Manufacturing

The route sheet provides information regarding the path the parts take through the job shop.
2. Flow Shop Manufacturing (Mass Production)

- *Specialized* equipment is used to manufacture a certain product, usually by making use of a *dedicated manufacturing* line.
- Less skilled labor is sufficient,
- Particular products are produced very economically provided that a *sufficient (high) quantity* is produced; since
- cost of a *specialized/dedicated* system is much higher than the cost of a general purpose system.
Flow Shop Manufacturing
Flow Shop Manufacturing

A transformation process in which successive units of output undergo the same sequence of operations with more specialized, dedicated equipment, usually involving a production line of some sort.

Economical for **large** amounts of production (**high** quantities).

(Nota: Job shop manufacturing is economical for **low** quantities.)
Flow Shop Manufacturing

Successive units of output undergo the same sequence of operations.
Manufacturing Systems

**Job Shop Manufacturing**

**Flow Shop Manufacturing**
Continuous Flow Shop Manufacturing

In **continuous flow shop manufacturing** which is usually chemical in nature the process goes on producing the exact same output or the same type of output in great volume (e.g. oil refinery, paper manufacturing).

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**Diagram Description:**
- The pine trees are cut down using equipment such as chain saws.
- Controlled lifting gear lifts the tree trunks onto trucks for transport to the pulp processing factory.
- Tree trunks are removed from the trucks by lifting equipment. The trucks are stockpiled for use 24 hours a day.
- Each trunk is fed into a chipping machine where it is cut into very small pieces. Mechanised equipment controlled by workers is used at this stage.
- The wood chips are boiled in water to form a thick wood pulp.
- Chemicals/ingredients such as starch and bonding agents are added. The pulp is poured over a fine mesh and the water escapes leaving the cellulose fibres behind. This forms the paper.
3. Project Shop Manufacturing

Directed toward creating a product or service which is either very large (immobile) or one-of-a-kind, with a set of well-defined tasks, which typically must be accomplished in some specified sequence.

The men, materials, and machines all come to the project site for assembly and processing (e.g. building construction, asphalt road plants).
Lot (Batch) production is a manufacturing process used to produce or process any product in batches, as opposed to a continuous production process which makes use of a line.

**Lot**

A collection (group) of things to be handled together; A specific quantity of parts produced in a process or series of processes.
Lot (Batch) Production

In the last 15 - 20 years, machine tools have become more powerful and versatile; cutting tools have become more effective, capable of cutting at faster speeds with reduced cutting forces.

But, it is observed that for machine tools used in lot (batch) production, only about half of the time at best is spent in making chips (on the average 45 %).
Lot (Batch) Production

- Only about half of the time at best is spent in making chips (on the average 45%).
- In 40% of the time machine is idle because of management problems,
- In 8% of the time idle because of operational problems,
- In 3% of the time idle for setting,
- In 2.5% of the time idle for tool adjustment,
- In 1.5% of the time idle for maintenance.
Group Technology (GT)

Group Technology deals with identifying and bringing together related or similar parts and processes, to take advantage of the similarities which exist, during all stages of design and manufacturing.

Group technology involves in grouping units or components into families wherein the components have similar manufacturing (or design) sequences.

Machines are then collected into groups or cells to process the entire family.

The machines in these groups are tooled so that one can rapidly change over from one part to another.

Thus, setup times are reduced to a matter of minutes or even eliminated.
Group Technology (GT)

Manufacturing Family

Design Family
When individual parts in the family are considered, their quantities are not sufficient to be manufactured by using a dedicated manufacturing line; but when the overall quantity of the parts in the family is considered, the quantity is sufficient to be manufactured by using a dedicated manufacturing line.

Since the parts in a family have similar manufacturing features, a machine (and tools) which can be used for a part can also be used for another part in the family.

A dedicated manufacturing line is used for manufacturing of different parts. (Provided that they have similar manufacturing features.)
- **Group** of machines, chosen for each **family**, are arranged together in a **group layout** (parts flow from one machine to the next in sequence of operations)
- The machines in these groups are **tooled** so that one can **rapidly change over** from one part to another.
- It is **not necessary** for every part to visit each machine, but the machines in a cell should be able to carry out all the required operations.
4. Cellular Manufacturing System

Uses work cells which have a number of machine tools (2 to 5) and inspection stations. Work cells can exist in two forms, being,

**Manned**, in which a worker who can operate all the machines, takes parts from the machines and places them in the automatic inspection devices, then takes good parts from the automatic inspection devices and places them in the next machine.

**Unmanned**, in which a robot is being used to load and unload the machines, which are Numerical Control (NC) type programmable machines.
Cellular Manufacturing System

Cycle time = 75 sec + 35 sec = 110 seconds
Longest machining time = 180 seconds
Total machining time = 280 seconds

All machines in the cell are capable of running untended while the operator(s) are doing manual operations (unload, load, inspection, deburr) or walking from machine to machine. The time to change tools and workholders (perform setup) is not shown.

Key:
DP = Drill press
L = Lathes
HM = Horizontal milling machine
VM = Vertical milling machine

Paths of workers moving within cell
Material movement paths
Operation sequence

Paths of workers moving within cell

<table>
<thead>
<tr>
<th>Work sequence</th>
<th>Name of operation</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mill ends on work on HM (1)</td>
<td>12&quot; 5' 30&quot;</td>
</tr>
<tr>
<td>2</td>
<td>Drill hole on DP</td>
<td>15&quot; 5' 20&quot;</td>
</tr>
<tr>
<td>3A or 3B</td>
<td>Turn - bore on L1 or L2</td>
<td>13&quot; 6&quot; 180&quot;</td>
</tr>
<tr>
<td>4</td>
<td>Mill flats on HM2</td>
<td>12&quot; 8&quot; 20&quot;</td>
</tr>
<tr>
<td>5</td>
<td>Mill steps on VM</td>
<td>13&quot; 7&quot; 30&quot;</td>
</tr>
<tr>
<td>6</td>
<td>Final inspect</td>
<td>10&quot; 5&quot;</td>
</tr>
</tbody>
</table>

3rd operation
Shaft cell

Parts
Out

Finished part
Final inspection

Key:

1. Paths of workers moving within cell
2. Material movement paths
3. Operation sequence
Cellular Manufacturing System

Manned

Unmanned
5. Flexible Manufacturing System (FMS)

Again uses **programmable machines**, but the material handling is accomplished by a **large conveyor system**.

The **parts are usually mounted on pallets** so that they can be shuttled to any of the machines, as needed.

**All the machines and the conveyor system are under the direct control of a computer.**

The system is designed to handle **larger families of parts** than the cellular system, and have **5 to 12 machines**.
Flexible Manufacturing System (FMS)

The transportation grid is comprised of a series of rectangles so that the transporter can go right, left, or straight ahead at any point of intersection except the outer edges.
Flexible Manufacturing System (FMS)

Flexible Manufacturing Systems are used for medium sized (100 to 10,000 units/year) batches. These systems integrate NC (CNC) machines with an automated material handling system, often incorporating computer control over all the machines and the materials handling system. Human labor is usually incorporated in material loading and unloading, changing worn tools, and performing equipment maintenance and repair.
Flexible Manufacturing System (FMS)

The workpieces can be launched randomly into the system, which identifies each part in the family and routes it to the proper machines.

The systems generally display reduced manufacturing lead time, low in-process inventory, and high machine tool utilization with reduced indirect and direct labor.

Machine tools are capable of changing cutting tools automatically to perform different tasks.