Concepts Of Manufacturing And Manufacturing Functions

History of Manufacturing

Manufacturing has been a human activity for a very long time. Ancient man produced stone articles by using his muscular power. Earlier manufacturing remained in the hands of Artisans and their apprentices and earlier developments in manufacturing took place in their supervision. Probably copper is the first metal melted by man. Excavations of Mohenjo-Daro and Harappa (5000 BC) shows the metal and jewellery work. There are examples of in Greek and Roman civilizations that their craftsman used casting process. Invention of copper, bronze and then Iron Age converted ancient civilization into Indus valley, China, Egypt, Mesopotamia and Babylon.

Concept of machining is also very old. It is believed that the idea of Lathe, the turning machine has been derived from the potter's wheel that existed before 2500 BC. The round groove marks on wooden bowls shows that turning was practiced as early as 1700 BC and was perfected before 6th century.

The concept of tool angles is also not new. The primitive man started thinking of tools in which a proper shaped tool used to be tied with wooden branch. Later, stone piece was replaced by the metallic piece. Idea of rotating stone wheel for producing sharp edges brought the concept of grinding. Wheels mounted on the spindle with crank for started appearing around 850 AD. The earliest known machine tool: Lathe (1400 AD) Earlier alternating motion was given to wooden work piece and tool was kept stationary on hands. Later a continuous unidirectional motion was attempted by winding an endless rope around a spindle and passing it over a flywheel which was rotated by hand. Wooden plank lath, so name Lathe has derived.

Drilling was carried by winding a cord on the sharp metallic linear piece and attaching its end to the rod. The art of forge welding was attempted during 2500 BC but it took a reasonably better shape around 1000 BC. Use of filler material started around 2500 BC A wire drawing set up in use around 1000 BC.

After the discovery of iron the development of hot forging, forge welding and grinding became imperative. The concept of grinding was although old but giving it unidirectional motion took many years (1450 AD). Many distinguishing features of modern machine tools were anticipated in design by small scale clock makers. During 1480 AD a German clock maker introduced the concept of screw cutting (quality was poor )on Lathe machine. After a long around 1780 AD Ramsden produced accurate screw thread cutting lathe by producing a series of screw threads.

During the latter half of 17th century use of timber was replaced by
coal for iron smelting but it could not lead to good results because used coal was surface coal. Thus deeper mining became a necessity but was a problem as no higher capacity pumps were available. Newcomen's engine was installed in coal mines but could not solve the purpose because of their huge size and inefficiency. James Watt (1762 AD) tried to solve the problem by using his steam engine up to a maximum. Watt patented (1769 AD) his engine however he failed to develop full size engine. His problem was to get accurate piston cylinder assembly. John Wilkinson (1728-1808 AD), the great iron maker, developed various kinds of water powered boring machines for producing iron cannons. He was the only cylinder maker who could face the challenges made by Watt. In 1775 AD Watt's attempt was successful. Later Wilkinson used Watt's engine to drive his boring machine.

- By the end of 18th century the steam engine power was available in large quantities at many locations which caused the First Industrial Revolution.

- This led to the growth of Production and Mechanization. The Soho Foundry (LONDON) was established in 1796 AD with steam engines was considered as Engineering Workshop of that time. By 1820 AD steam power driven machine tools were ready for the sale.

- Now the need for high strength material was felt which was met by Carbon Steels. Liebig (1831 AD) could perfectly analyze and determine the effect of carbon on the strength of steel. This started the age of Steels and it became possible to produce rigid and precision machines.

- Henry Maudslay (1771-1831 AD) brought several new concepts in machine tool design. He introduced the tool slide and rest with tool head in 1794 AD. It was equipped with lead screw and had provision for taper turning. He also produced number of screw cutting machines. In 1805 AD, first micrometer was designed by him.

- During 1825-1865 AD machine tools like planning, shaping, drilling, punching slotting, milling etc. were developed.

- The need for strong marine vessel led to introduction of rolling mills that produced iron flats for ships which crossed Atlantic in 1883 AD. These rolled material also met the requirements for multi-storeyed buildings etc.

- By the mid of 19th century Britain became the leading country in science and technology.

- True industrial revolution started when the concept of mass production was introduced in 1748 AD to lower the
production cost so that the benefits of engineering could reach to common man.

- Proliferation of machines started and a large number of special purpose machines, automatic and semi automatic machines were designed and developed. The trend was to move towards mechanization and hard automation.

- Whitney introduced the concept of interchange ability in the end of 18th century.

- This needed more close tolerances therefore need for high speed stone tools (grinding) felt and development in precision grinding took place around 1900 AD.

- Significant improvement in welding processes also took place during this time. Use of metallic molds and patterns came into scene so that precise casting could be achieved.

- Polymer products were developed during 1925-1950 AD due to requirement of high strength to weight ratio. Introduction of hard, temperature resistant materials led to development of various unconventional machining processes during 1960s.

- Second industrial revolution started during mid of 20th century with the enormous growth in solid state electronics and computers that can perform tasks very rapidly efficiently with lower cost.

- In this age attempt was to enhance and sometimes even replace the mental efforts. The trend was now to move towards flexible automation.

- Today the era of mass production and hard automation is going away and is being replaced by batch production and flexible automation.

- The first step in this direction is numerically Controlled machine tools in which the motion of slides is controlled by numerals and letters. The microprocessor based systems and feedback devices provide better accuracy and precision.

Historical development of manufacturing processes
**Introduction to production systems**

The production system is the collection of people, equipment, and procedures organized to accomplish the manufacturing operations of a company.

Production systems can be divided into two categories and the levels are shown in figure below.
the production system consists of facilities and manufacturing systems

*Facilities:* the facilities of the production system consist of the factory and the equipment in the facility.

*Manufacturing support systems:* the set of procedures used by a company to manage production and to solve technical and logistics problems in ordering materials, moving work through the factory, and ensuring that products meet quality standards.

**Production system facilities**

The facilities in the production system are the factory, production machines and tooling, material handling equipment, inspection equipment, and computer systems that control the manufacturing operations. Facilities include the factory, production machines and tooling, material handling equipment, inspection equipment, and computer systems that control the manufacturing operations.

*Plant layout:* which is the way the equipment is physically arranged in the factory.

*Manufacturing systems:* The equipment is usually organized into logical groupings, and we refer to these equipment arrangements and the workers who operate them as the manufacturing systems in the factory.

Production quantity refers to the number of units of a given part or product produced annually by the plant. The annual part or product quantities produced in a given factory can be classified into three ranges:

- **Low production:** Quantities in the range of 1 to 100 units per year
- **Medium production:** Quantities in the range of 100 to 10,000 units annually.
- **High production:** Production quantities are 10,000 to millions
There is an inverse relation correlation between product variety and production quantity in terms of factory operations. When the product variety is high, production quantity tends to be low and vice versa. This relationship is shown in figure 1.2. Manufacturing plants tend to specialize in a combination of production quantity and production variety that lies somewhere inside the diagonal band in figure 1.2. In general, a given factory tends to be limited to the product variety value that is correlated with that production quantity.

The relation between product variety and production quantity

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., between car models made on the same production line, with many common parts among models.

- **Hard product variety** - products differ substantially, e.g., between a small car and a large truck, with few common parts (if any).

Low Quantity Production

Job shop makes low quantities of specialized and customized products are typically complex (e.g., specialized machinery, prototypes, and space capsules) and the equipment is general purpose and the labor force is highly skilled. A job shop must be designed for maximum flexibility to deal with the wide part and product variations encountered (hard product variety). If the product is large and heavy, and therefore difficult to move in the factory, it typically remains in a single location, at least during its final assembly. Workers and processing equipment are brought to the product, rather than moving the product to the equipment. This type of layout is referred to as a fixed position layout as shown in figure 1.3(a).
The individual parts that comprise these large products are often made in factories that have a process layout, in which the equipment is arranged according to function or type. The lathes are in one department, the milling machines are in another department, and so on, as in figure 1.3(b).

![Various types of plant layout](image)

**Figure 1.3**

(a) fixed position layout, (b) process layout, (c) cellular layout, and (d) product layout.

**Medium Quantity production**

In the medium quantity production, we distinguish between two different types of facility, depending on product variety. When the product variety is hard, the traditional approach is *batch production*, in which a batch of one product is made, after which the facility is changed over to produce a batch of the next product, and so on. The equipment is usually arranged in a process layout, figure 1.3(b). The processing or assembly of different parts or products is accomplished in cells consisting of several workstations or machines. The term *cellular manufacturing* is often associated with this type of production. The layout is called a *cellular layout* shown in figure 1.3(c).

**High Production**

The high quantity range is often referred to as mass production. Mass production can be divided into two types.

1. Quantity production
Quantity production involves the mass production of single parts on single pieces of equipment. The typical layout used in this is the process layout, figure 1.3(c).

2. Flow line production

Flow line production involves multiple workstations arranged in sequence, and the parts or assemblies are physically moved through the sequence to complete the product. The collection of stations is designed specifically for the product to maximize efficiency. The layout is called a product layout, and the workstations are arranged into one long line, as in figure 1.3(d).

The most familiar example of flow line production is the assembly line, associated with products such as cars and household appliances. The pure case of flow line production is where there is no variation in the products made on the line. Every product is identical, and the line is referred to as a single model production line, to successfully market a given product. The term mixed model production line applies to those situations where there is soft variety in the products made on the line. Most of our discussion of the types of production facilities is summarized in figure

**types of facilities and layouts used for different levels of production quantity and product variety**

Manufacturing support systems

A company must organize itself to design the processes and equipment, plan and control production, and satisfy product quality requirements. Accomplished by manufacturing support systems - people and procedures by which a company manages its production operations the typical departments are:

1. Manufacturing engineering
2. Production planning and control
3. Quality control
It involves a cycle of information-processing activities that consists of four functions:

1. Business functions - sales and marketing, order entry, cost accounting, customer billing.
2. Product design - research and development, design engineering, prototype shop.
3. Manufacturing planning - process planning, production planning, MRP, capacity planning.
4. Manufacturing control - shop floor control, inventory control, quality control.

Information Processing Cycle in Manufacturing Support Systems

5. Shop floor control deals with the problem of monitoring the progress of the product as it is being processed, assembled, moved, and inspected in the factory.
6. Inventory control attempts to strike a proper balance between the danger of too little inventory and the carrying cost of too much inventory.
7. Quality control mission is to ensure that the quality of the product and its components meet the standards specified by the product designer.

Computer Integrated Manufacturing
Automated Manufacturing Systems

Automated manufacturing systems operate in the factory on the physical product. They perform operations such as processing, assembly, inspection, or material handling in some cases accomplishing more than one of these operations in the same system. Examples of automated manufacturing systems include:

- Automated machine tools and Transfer lines
- Automated assembly systems
- Industrial robots that perform processing or assembly operations
- Automated material handling and storage systems to integrate manufacturing operations and Automatic inspection systems for quality control

Automated manufacturing systems can be classified into three basic types:

1. **Fixed automation**

   A manufacturing system in which the sequence of processing (or assembly) operations is fixed by the equipment configuration typical features:

   - Suited to high production quantities
   - High initial investment for custom-engineered equipment
   - High production rates
   - Relatively inflexible in accommodating product variety

2. **Programmable automation**

   A manufacturing system designed with the capability to change the sequence of operations to accommodate different product configurations typical features:

   - High investment in general purpose equipment
   - Lower production rates than fixed automation
   - Flexibility to deal with variations and changes in product configuration
   - Most suitable for batch production
   - Physical setup and part program must be changed between jobs (batches)

3. **Flexible automation**

   A manufacturing system designed with the capability to change the sequence of operations to accommodate different product configurations typical features:
- High investment in general purpose equipment
- Lower production rates than fixed automation
- Flexibility to deal with variations and changes in product configuration
- Most suitable for batch production
- Physical setup and part program must be changed between jobs (batches)

Product Variety and Production Quantity for Three Automation Types

Computerized Manufacturing Support Systems

Objectives of automating the manufacturing support systems:

- To reduce the amount of manual and clerical effort in product design, manufacturing planning and control, and the business functions
- Integrates computer-aided design (CAD) and computer-aided manufacturing (CAM) in CAD/CAM
- CIM includes CAD/CAM and the business functions of the firm

Reasons for Automating

Companies undertake projects in manufacturing automation and computer integrated manufacturing for a variety of good reasons. Some of the reasons used to justify automation are the following:

1. To increase labor productivity: Automating a manufacturing operation usually increases production rate and labor productivity.
2. To reduce labor cost: Ever increasing labor cost has been and continues to be the trend in the world's industrialized societies.
3. To mitigate the effects of labor shortages: There is a general shortage of labor in many advance nations. And this has stimulated the development of automated operations as a substitute for labor.
4. To reduce or remove routine manual and clerical tasks: An argument can be put forth that there is social value in automating operations that are routine, boring, fatiguing, and possibly irksome.
5. To improve worker safety: by automating a given operations and transferring the worker from active participation in the process to supervisory role.
6. To improve product quality: Automation not only results in higher production rates than manual operations.
7. To reduce manufacturing lead time: Automation helps to reduce the elapsed time between customer order and product delivery.
8. To accomplish what cannot be done manually: Certain operations cannot be accomplished without the aid of a machine.
9. To avoid the high cost of not automating: There is a significant competitive advanced gained in automating a manufacturing plant.

Manual Labor in Production Systems

Is there a place for manual labor in the modern production system? Answer: YES

Let us separate labor issue into two aspects, corresponding to distinction between the facilities and manufacturing support.

1. **Manual labor in factory operations**

The long term trend is toward greater use of automated systems to substitute for manual labor. When is manual labor justified? Some countries have very low labor rates and automation cannot be justified.

- Task is too technologically difficult to automate
- Short product life cycle
- Customized product requires human flexibility
- To cope with ups and downs in demand
- To reduce risk of product failure

2. **Labor in manufacturing support systems**

Product designers who bring creativity to the design task. Manufacturing engineers who Design the production equipment and tooling and plan the production methods and routings, Equipment maintenance, Programming and computer operation, Engineering project work, Plant management.
Automation principles and strategies

In this section, we offer three approaches for dealing with automation products:

1. **U.S.A principle**
   - The USA principle is a common sense approach to automation projects. Similar procedures have been suggested in the manufacturing and automation trade literature. Understand the existing process
     - Input/output analysis
     - Value chain analysis
     - Charting techniques and mathematical modeling
   - Simplify the process
     - Reduce unnecessary steps and moves
   - Automate the process
     - Ten strategies for automation and production systems
     - Automation migration strategy

2. **Ten strategies for automation and production systems**

Following the USA principle is a good first step in any automation project. If automation seems a feasible solution to improving productivity, quality, or other measure of performance, then the following ten strategies provide a road map to search for these improvements. We refer to them as strategies for automation and production systems because some of them are applicable whether the process is a candidate for automation or just for simplification.

**Those strategies are:**

- Specialization of operations
- Combined operations
- Simultaneous operations
- Integration of operations
- Increased flexibility
- Improved material handling and storage
- On-line inspection
- Process control and optimization
- Plant operations control
- Computer-integrated manufacturing

3. **Automation migration strategy**

<table>
<thead>
<tr>
<th>Phase</th>
<th>Strategy</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Manual</td>
<td>Single-station manned cells working independently</td>
</tr>
<tr>
<td></td>
<td>production</td>
<td>Advantages: quick to set up, low-cost tooling</td>
</tr>
<tr>
<td>2</td>
<td>Automated</td>
<td></td>
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</tbody>
</table>


Single-station automated cells operating independently
As demand grows and automation can be justified

Phase 3  ❯ Automated integrated production
Multi-station system with serial operations and automated transfer of work units between stations

Automation Migration Strategy

Overview of manufacturing

Manufacturing can be defined as 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 the joining of multiple parts to make assembled products. The processes that accomplish manufacturing involve a combination of machinery, tool, power, and manual labour, as shown in figure 1.9(a)

From an economic point of view, manufacturing is concerned with the transformation of materials into items of greater value by means of one or more processing and/or assembly operations as shown in figure 1.9(b).
Alternate definitions of manufacturing (a) as a technological process and (b) as an economic process

Production operations in the process industries and the discrete product industries can be divided into continuous and batch production. The differences are shown in figure

Process Industries and Discrete Manufacturing Industries

Manufacturing Operations:

There are certain basic activities that must be carried out in a factory to convert raw material into finished products.

1. Processing and assembly operations
2. Material handling
3. Inspection and test
4. Coordination and control

The first three activities are the physical activities that touch the product as it is being made.
Classification of manufacturing processes

Production concepts and Mathematical Models:

The various factors influencing the production line are Production rate \( R_p \), Production capacity \( PC \), Utilization \( U \), Availability \( A \), Manufacturing lead time \( MLT \), Work-in-progress \( WIP \).

Typical cycle time for a production operation:

\[ T_c = T_o + Th + T_{th} \]

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

Batch production:

Batch production 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 \( T_{su}/Q \approx 0 \)

For flow line production

\[ T_c = T_r + \text{Max } T_o \] and \( R_c = \frac{60}{T_c} \)

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

\[ PC_w = n \]

\[ Sw \]

\[ H_s \]

\[ R_p \]

where \( PC_w \) = weekly plant capacity, units/wk
Plant capacity for facility in which parts require multiple operations ($no > 1$):

$$PC_w =$$

where $no =$ number of operations in the routing

Utilization: $U =$

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

Availability: $A =$

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

Manufacturing lead time $MLT = no (Tsu + QTc + Tno)$

where $MLT =$ manufacturing lead time, $no =$ number of operations, $Tsu =$ setup time, $Q =$ batch quantity, $Tc =$ cycle time per part, and $Tno =$ non-operation time

Work in process $WIP =$

where $WIP =$ work-in-process, $pc;$
$A =$ availability, $U =$ utilization, $PC =$ plant capacity, $pc/wk;$
$MLT =$ manufacturing lead time, $hr;$
$Sw =$ shifts per week, $Hsh =$ hours per shift, hr/shift

Costs of Manufacturing Operations:

- Two major categories of manufacturing costs:
  - Fixed costs - remain constant for any output level
  - 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.

Typical manufacturing costs:

the various costs of the manufacturing industries