CHAPTER | FOUR

Production Processes, Manufacturing and Service Operations

Learning Objectives

After reading this chapter, you should be able to:

- Understand the meaning of production process.
- Describe the various categories of manufacturing processes.
- Differentiate between manufacturing and service operations.
- Discuss the various heat-treatment processes and surface treatment processes.
- Discuss the primary characteristics of service.
- Discuss the differences and similarities between manufacturing and service operations.

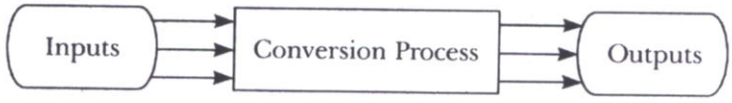
PRODUCTION PROCESSES

Products are the goods and services produced and processes are the facilities, skills and technologies used to produce them. Production processes are essential to produce products and the available processes limit what products can be produced.

Production processes : Conversion or transformation processes used to produce products.

Production function or operations function is the primary function of an industrial enterprise. It is also known as ***conversion process*** or ***transformation process*** which transforms some of the inputs (raw materials and components) into outputs which are useful for the consumers. (*Exhibit. 4.1*)

Exhibit 4.1 : A Simple Production System



The outputs should have more value to the consumer than the cost of producing them.

MANUFACTURING OPERATIONS AND SERVICE OPERATIONS

Manufacturing operations or processes convert inputs into tangible outputs.

The field of operations can be divided into manufacturing operations and service operations.

Manufacturing Operations

Manufacturing operations convert inputs like materials, labour and capital into some tangible outputs.

Three basic catagories of manufacturing processes are:
- **Forming processes**
- **Machining processes**
- **Assembly processes.**

Manufacturing processes are the primary processes and can be grouped under three basic categories, namely, *forming, machining* and *assembly*. The objectives of each process is to change the shape or physical characteristics of the raw materials.

(i) **Forming processes**

Include casting, forging, stamping, embossing, spinning etc. These processes change the shape of the work piece without necessarily removing or adding material.

(ii) **Machining processes**

Involve basically metal removal, by turning, drilling, milling, grinding, shaping, boring etc., it also includes chipless machining processes such as electro discharge machining (EDM), electrochemical machining (ECM), chemical milling, laser drilling etc.

(iii) **Assembly processes**

Involve the joining of component or piece parts to produce a single component that has a specific function. Some of the common assembly processes are welding, brazing, soldering, riveting, fastening with bolts and nuts and joining by use of adhesives.

SELECTION OF A PROCESS

The selection of a manufacturing process is influenced by several factors such as the desired product quality, labour cost to be achieved and the volume of production needed. While there can be several manufacturing methods or processes to produce an item, there is usually one best method for a given set of variables.

Some of the common manufacturing processes are briefly described in the following paragraphs.

Forming Processes

Forming Processes: Include casting, forging, extrusion, stamping, embossing and coining, spinning etc., which change the shape of the work piece without necessarily removing or adding material.

(a) Casting

The casting process consists of pouring of molten metal into a mould and allowing sufficient time for the metal to solidify and retain the shape of the moulded cavity. The various casting methods are sand casting, shell moulding, gravity die casting, pressure die casting, centrifugal casting, investment casting etc. Casting of plastics is done by compression moulding, injection moulding, transfer moulding, extrusion, vacuum forming and blowing.

(b) Forging

In forging process the metal is heated to a plastic state and then formed to the desired shape by pressure or impact. The various types of forging processes are flat die forging, drop forging, upset forging, press forging and roll forging.

(c) Extrusion

Extrusion process consists of forcing the metal through dies so that the metal obtains cross section of the same shape as the die. Extrusion process can be direct or forward extrusion, inverted or backward extrusion and impact extrusion.

(d) Stamping

In the stamping process, force is applied on the metal to cause plastic flow and to alter the size and shape of the metal part to the desired size and shape. It is a cold working process.

(e) Embossing and Coining

In embossing, the metal is stretched or formed as per the configuration in the dies. Coining is performed in an enclosed die and the metal flow is restricted in a lateral direction.

An impact or compressive force causes the metal to flow in the shallow configurations of the blank being coined.

(f) Spinning

Also known as spin forming, it is a process of shaping a metal by pressing it against a form or mandrel while it is rotating on a high speed lathe.

Machining Processes

Machining Processes: Remove the metal from the work piece during the cutting operation performed by a cutting tool. Examples are turning, milling, drilling, boring, grinding, shaping, planing, chemical milling, electro-chemical milling and electro discharge machining.

Machining process removes the metal from the work piece during the cutting operation performed by a cutting tool. Its prime function is to alter the shape of the work piece or raw material, provide proper surface finish and dimensional accuracy. Some of the machining processes are

(a) Turning

In turning operation, the work piece is held in the lathe and rotated while the cutting tool or cutter removes the metal from the work piece. The various kinds of operations that can be performed on lathe are cylindrical turning, taper turning, facing, reaming, drilling, boring, thread cutting, grinding and knurling.

(b) Drilling and boring

In drilling operation, a hole is produced on the work piece by forcing a rotating cutter known as *drill bit* through the workpiece.

In *boring* operation, an existing drilled hole is enlarged by using a cutter known as *boring bit*.

Reaming is the finishing of a drilled hole to an accurate size using a fluted tool called a *reamer*.

(c) Milling

Milling operation removes metal by feeding the work piece against a rotating multi-point cutting tool called *milling cutter*.

(d) Grinding

Grinding process refers to the abrading or wearing away by friction of a material. It is accomplished by forcing the work piece against a rotating grinding wheel made of abrasive material. Extremely hard metals or metals hardened by heat treatment processes can be machined only by the grinding process.

(e) Shaping and planing

In shaping or planing, plane surfaces are produced with the use of single point cutting tools. Work pieces, castings or forgings of smaller sizes are machined by shaping process whereas planing process is used for machining work pieces, castings or forgings of larger sizes.

(f) Electro-discharge machining (EDM)

It is a 'chipless' process using electrical energy for metal removal. The operation involves producing a spark between the work piece and the tool across a gap between them. The work piece melts at the contact point of the spark and the molten metal is removed by the die-electric which also cools the work piece and the tool.

(g) Electrochemical machining (ECM)

This is also a "chipless" process, but it differs from EDM in that chemical energy combines with electrical energy to do the cutting operation. It is opposite of the electroplating process. In ECM the metal to be removed is dissolved off the work piece and carried away by the electrolyte.

(h) Chemical milling

This process removes metal by chemical action. It is an etching process with carefully controlled chemical reaction. Precleaning, masking, etching and stripping are the operations that must be performed in chemical milling.

Assembly Processes

(a) Welding processes

Assembly Processes: Involve joining of component or piece parts to produce a single component. Examples are : welding, brazing, soldering, riverting, fastening by bolts and nuts and assembly using adhesives.

In welding process, two pieces of metal are joined into a single piece by fusion due to heat or combination of heat and pressure. Various types of welding processes are gas welding, arc welding, resistance welding (spot welding and seam welding), plasma arc welding, electron beam welding and laser welding.

(b) Brazing

Brazing is a metal joining process used for joining nonferrous alloys (either similar or dissimilar metals). The brazing alloy melts at a lower temperature than the melting point of the base metals to be joined and fills the joint between the base metals by capillary action and then solidifies on cooling.

(c) Soldering

Soldering process is similar to brazing except that the soldering alloy is different from brazing alloy and melts at a lower temperature as compared to brazing alloy. The lead-tin base solder alloys melt and flow throughout the solder joint by the heat of the joint itself.

(d) Riveting

It is the process of placing the rivet in a hole drilled through the overlapping surfaces of the work pieces to be joined and upsetting the head of the rivet using a riveting tool.

(e) Fastening by bolts and nuts

When workpieces or parts of an assembly must be disassembled and reassembled, the best method of assembly is by fastening using screws, bolts and nuts.

(f) Assembling using adhesives

Adhesives are used to bond almost all materials such as wood, rubber, plastics and metals.

NON-MANUFACTURING OR SERVICE OPERATIONS

Service operations: Non-manufacturing operations which also convert inputs into outputs which are intangible.

Non-manufacturing or service operations also transform a set of inputs into a set of outputs but the outputs are not tangible. Service operations can be classified into *standard services* and *custom services* according to the degree of standardization of their outputs and/or the processes they perform.

Some non-manufacturing operations such as wholesale distribution and freight transportation deal with tangible products whereas some non-manufacturing operations such as advice, consulting or consultancy deal only in intangible products.

An operation does not necessarily provide only service or only goods. Facilitating goods may be provided with services and facilitating services may be provided with goods. For example, same goods can be bought from a grocery store or from a superbazar. Also servicing of automobiles may include the replacement of some parts (i.e., spare parts).

Some of the examples of non-manufacturing operations which provide tangible goods are mail service, library service, and wholesale and retail distribution. Some of the non-manufacturing operations which provide only services and not tangible goods are health care, hair dressing, travel service, legal advice, marriage consultancy.

DIFFERENCES BETWEEN MANUFACTURING AND SERVICE OPERATIONS

(i) Productivity can be more easily measured in manufacturing operations than in service operations because manufacturing operations produce tangible products whereas outputs of service operations are generally intangible.

(ii) Quality standards are more difficult to establish and product quality is more difficult to evaluate in service operations. They are relatively simple and easy in manufacturing operations.

(iii) Customers have more contact with persons who provide services than with those who perform manufacturing operations.

(iv) In continuous production of standard products, manufacturing operations can accumulate or decrease inventory of finished product, whereas non-manufacturing operations can not produce outputs that can be stored.

(v) The proportion of expenses required for material handling is more in manufacturing operations than for non-manufacturing operations.

(vi) Investments in assets such as facilities, equipments and inventory are higher in manufacturing organizations than in service organizations.

(vii) Manufacturing operations depend more heavily on maintenance and repair work than non-manufacturing operations.

Table 4.1 illustrates the distinction between products of manufacturing operations and services of non-manufacturing operations.

Table 4.1 : Characteristics of Manufactured Products and Services

Manufactured Products	*Services*
Tangible outputs	Intangible outputs
Products can be inventoried	Outputs cannot be inventoried
Little customer contact	Extensive customer contact
Long lead times	Short lead times
Capital intensive	Labour intensive
Product quality easily determined	Service quality determined with difficulty

I CLASSIFICATION OF MANUFACTURING PROCESSES

Manufacturing processes may be classified as :

1. *Processing* (a) Heavy processing
   (b) Light processing
2. *Treatment* (a) Heat treatment
   (b) Surface treatment
3. *Fabrication* (a) Heavy fabrication
   (b) Medium fabrication
   (c) Light fabrication

Processing

Heavy processing industries include processing industries for industrial metals such as steel and copper and also heavy chemical industries manufacturing sulphuric acid and heavy alkalies. These are continuous production industries.

Light processing industries include processing industries that produce chemical compounds, drugs and some metals for e.g., boron and titanium. It also includes industries manufacturing plastics.

Treatment

Heat treatment of steel alloys is needed to obtain certain desired mechanical properties such as hardness, toughness etc.,

Surface treatment refers to the chemical or mechanical processes which are used to alter the surface characteristics of a metal.

Fabrication

Heavy fabrication includes fabrication of large and heavy parts or assemblies made of iron and steel incorporating castings, forgings, welded structures and parts made of thick metal plates, e.g., manufacture of locomotives, earth moving equipments, electric generators, boilers etc.

Medium fabrication includes forgings and castings and assembly work for manufacturing products such as automobiles, aircrafts, missiles, etc.

Light fabrication involves manufacture of products such as utensils, bicycles and furnitures involving conventional manufacturing methods and mass production assembly lines.

Since heat treatment and surface treatment are more commonly used processes, they are described in greater detail below:

Heat Treatment Processes

Heat treatment is the process of heating and cooling of metals or alloys in the solid state in order to obtain certain desired properties.

Heat treatment processes: Involve heating and cooling of metals or alloys in the solid state to obtain certain desired properties. Examples: annealing, normalising, hardening and case-hardening.

By heat treatment processes it is possible to alter the properties of a metal or alloy, to make it more suitable for a particular application. Steels are especially suitable for heat treatment because of the polymorphic change of iron *as austenite* which transforms during cooling. The crystalline structure and therefore the mechanical properties of steel can be greatly affected by suitable heat treatment processes. The important heat-treating processes for steels are hardening, tempering, annealing, normalising and case hardening.

Purpose of Heat Treatment

(i) To improve machinability of a metal or alloy

(ii) To relieve internal stresses

(iii) To improve mechanical properties such as hardness, toughness, strength and ductility.

(iv) To improve electrical and magnetic properties

(v) To increase resistance to heat and corrosion

(vi) To change the chemical composition

(vii) To refine the grain size and grain structure

For example, hardness and toughness of alloy steels must be increased when they are used to manufacture cutting tools.

Gear teeth must be case hardened to reduce wear and tear.

Heat treatment is used to obtain optimum combination of hardness and ductility for carbon steels and alloy steels for a particular application.

Heat treatment generally involves heating of metals and alloys to a certain temperature and holding at that temperature for certain length of time and then cooling slowly or rapidly (at different cooling rates) in order to change the microstructure of the metals to get the desired mechanical properties.

Methods of Heat Treatment

Methods of heat treatment are:
- **Annealing**
- **Normaliaing**
- **Hardning**
- **Tampering**
- **Care hardning**

The most important heat treatment processes are:

(1) annealing, (2) normalising, (3) hardening, (4) tempering, (5) case hardening.

All heat treatment processes basically involve.

(i) The ***heating*** of the metal to the ***predetermined temperature*** depending on the shape, size and composition of the parts heat treated.

(ii) The ***soaking*** of the parts at that temperature until the structure becomes uniform throughout the mass.

(iii) The ***cooling*** of the metal at some ***predetermined rate*** to cause the formation of desirable structures within the metal/alloy to obtain the desired mechanical/electrical properties.

Annealing

Annealing is one of the most widely used heat-treatment processes carried out for softening the metal so that it can be machined more easily.

Annealing: Process of heating and cooling the metal to soften the metal, relieve internal stresses and refine the grain structure. Classified as process annealing and full annealing.

The purpose of annealing is to obtain one or more of the following effects :

(i) Softening metal or alloy in order to improve its machinability.

(ii) Relieving internal residual stresses caused by various manufacturing processes such as forging, forming, machining, rolling, hammering etc.

(iii) Refining the grain size of the metal or alloy.

(iv) Increasing ductility and toughness.

Annealing can be classified into:

(a Process annealing and

(b) Full annealing

(a) ***Process annealing*** is used to remove the internal stresses and to refine the granular structure. This consists of heating the steel to a temperature just below its critical point (usually about 800°C to 850°C) and allowing it to cool very slowly inside the heat-treatment furnace itself.

(b) ***Full annealing*** is carried out by heating to a temperature of approximately 30° C to 50° C above the critical point, maintaining this temperature until all the material has changed to austenite and then cooling slowly in the furnace, hot sand or fine ashes.

Normalising

Normalising: Involves heating the metal to a temperature below the critical point, holding at that temperature for some time and then cooling in still air outside the furnace. It obtains uniform grain structure and improves machinability.

When steel is cold worked, the crystalline structure is distorted and the metal becomes brittle. Normalising implies heating of the steel to the same temperature as that employed for full annealing (*i.e.,* 30° C to 50° C above the critical point) and then holding at that temperature for about 15 minutes and then cooling in still air at room temperature outside the furnace. The higher rate of cooling than that is obtained during annealing maintains a fine structure of ***pearlite*** and this results in higher strength in normalised steel than annealed steel. Normalising is a modified form of annealing.

The purpose of normalising is –

(i) To eliminate coarse grain structure and to obtain uniform grain structure in the metal.

(ii) To remove the internal stresses caused by cold working or machining.

(iii) To improve the machinability.

(iv) To improve the mechanical properties.

(Normalised steels have a higher yield point, tensile strength and impact strength than annealed steels but ductility and machinability obtained by normalising will be somewhat lower than that obtained by annealing)

(v) For many steels the surface finish obtained by machining processes on a normalized steel is found to be superior to that obtained with an annealed steel.

(vi) Normalising renders the metal more homogeneous.

Hardening

Hardening is the process of heating the metal (steel of carbon content greater than 0.2 percent) to a temperature for a considerable period of time and then cooling rapidly (*i.e.,* quenching) in a quenching medium such as water, oil or brine (*i.e.,* salt water). Hardening is usually followed by tempering to reduce the brittleness of hardened steel.

The purpose of hardening is to impart high hardness to steel used in cutting tools to reduce wear and tear and to enable it to cut other metals. Besides, hardening improves the strength, ductility and toughness of steel.

Hardening: Process of heating the metal to a certain temperature above the critical point for a considerable period of time and then cooling rapidly in a quenching medium and subsequently tempering to reduce brittleness.

Requirements for Hardening

The requirements for hardening of steel are —

(i) Composition, carbon and alloy content of steel

(ii) Homogeneity of austenite and its grain size

(iii) Rate and time of heating and the temperature to which steel is heated

(iv) Quenching medium used and the rate of cooling or quenching.

(v) The mass and surface condition of the charge. (*i.e.*, the job heat treated)

Normally steel containing more than 0.8% carbon is more suitable for hardening.

The more rapidly a steel part is quenched, the harder and the stronger it becomes. Water as a quenching medium is better than oil and brine solution is better than water if a rapid cooling rate is desired.

Tempering

When steel is quenched in a quenching medium in the hardening process, it becomes hard, brittle and will have uneven internal stresses.

Tempering: Process of reheating the hardened steal to a temperature below the critical point, holding for a considerable time and then cooling slowly. It reduces the internal stresses caused by hardening, reduces brittleness and improves toughness.

Tempering process is used to reheat the hardened steel to a temperature below the critical point, holding it for a considerable time and cooling slowly. The reheating temperature ranges from 150° C to 650° C depending on the purpose of the part that is hardened. The cooling media may be mineral oils or liquid salt baths containing mixture of nitrates, chlorides or fluorides. Tempering reduces the internal stresses, reduces brittleness and improves toughness of the metal and also increases ductility of the metal.

Surface Hardening or Case Hardening

Surface hardening or case hardening is the process of adding carbon to the outer surface of a metal in order to harden low carbon steels or mild steels. The carbon so added forms a hard and thin outer case.

For some applications, steel parts should posses hard, wear resisting surfaces while their interiors are sufficiently tough to resist sudden impact or shock. Most case hardening processes start with a low carbon, tough, shock-resistant steel and cause carbon to diffuse into the surface. As a result the steel parts will have a case of high-carbon steel.

Three Methods of Case Hardening

(i) pack carburizing, *(ii)* nitriding, *(iii)* cyaniding.

Pack carburizing: A case hardening method in which parts are packed with charcoal in metal boxes and then heated to a suitable temperature in a furnace for some time and then cooled in the surface.

In ***pack carburizing***, steel parts are packed in gas-tight, cast-iron or alloy-steel boxes with charcoal. These boxes are then heated in suitable furnaces to the proper temperature. The oxygen within the boxes combines with carbon from charcoal to form carbon monoxide gas. When carbon monoxide comes into contact with the heated steel, it gives up carbon which diffuses into the steel. The oxygen is then free to combine with more carbon from the charcoal. The depth of the high-carbon case obtained depends upon the temperature and time duration of the process. Case depths upto ¼ inch (or 6 mm) are obtained by pack carburizing. After carburizing the case must be hardened and tempered so that the outer surface becomes hard and tough.

Cyaniding is the method of case hardening by immersing the steel into a molten bath of a suitable carburizing salt and afterwards quenching. Not only are the results obtained more uniform but the process is cleaner and quicker than pack carburizing. The most suitable salt to be used is sodium cyanide which melts at higher temperatures. Sometimes a bath containing

Cyaniding: A method of case hardening by immersing steel into a molten bath of carburising salt and then quenching.

equal amounts of sodium chloride, sodium carbonate and sodium cyanide is also used. The salt bath is maintained at a temperature of 800° C to 900° C. The steel parts are immersed in the molten-salt bath at 800° C to 900° C and then quenched in water or oil or in caustic soda bath. The carbon and nitrogen of the cyanide salt are the two active carburizing agents. Under normal condition a case depth of 0.125 mm will be produced in about 15 minutes at 850° C. The maximum case depth that can be obtained by cyaniding process is about 0.8 mm.

Advantages of cyaniding process are :

(a) Bright surface finish of machined parts can be maintained

(b) Distortion of case hardened parts can be avoided

(c) More suitable for obtaining shallow case depths. (Up to about 0.008 inch or 0.2 mm)

Nitriding: A heat treatment process in which steel parts to be case hardened are heated in ammonia gas in a furnace for a considerable time period.

Nitriding *process* consists of heating steel parts in gas which contains high concentration of nitrogen so that the nitrogen diffuses into the surface of the steel. Usually ammonia gas is used. The nitriding process consists of heating the metal to 550° C and holding or soaking for about 96 hours. The ammonia gas dissociates to produce nitrogen. Nitrogen combines with iron to form iron nitride, which is extremely hard and brittle. Low carbon steels are not suitable for nitriding because the case produced is too brittle. A nitride case after absorption of nitrogen is fully hard, so that no quenching or additional heat treating is necessary. Nitride cases are usually 0.020 inch or 0.5 mm thick.

Advantages of nitriding are :

(a) Simple and low cost

(b) No stresses or distortions are caused. There is no quenching.

(c) Dimensional changes during the process are negligible.

(d) The surfaces are extremely hard.

(e) It is possible to mask surfaces which are to remain soft.

Heat Treatment of Nonferrous Metals

The heat treatment processes applied to the nonferrous metals are more limited in scope than those applied to the ferrous group. Non ferrous metals can be annealed and the other processes used are 'solution heat treatment' and 'precipitation hardening'.

I SURFACE TREATMENT OF METALS

The ordinary metals and alloys which are used for industrial, domestic and other purposes, so readily corrode or tarnish when exposed to the atmosphere, that it is necessary to treat the surface in some way that will enable the metal to resist corrosion or tarnishing for the longest possible period. Coating is used on most metal products either for protective or decorative purposes or for both.

The key to successful surface finishing is to clean the surface first to ensure good adhesion of a coating given either by electroplating process or by painting process or by plastic coating process. The various surface treatment processes are :

Cleaning of Metals

Cleaning is done both before and after finishing operations. Cleaning is done to remove dirt, oil, oxides, rust and scales.

Chemical cleaning is the most popular method of cleaning. Various methods used are alkaline pickling, acid pickling, solvent cleaning, electrolyte cleaning, vapour degreasing and ultrasonic cleaning.

Mechanical cleaning methods are used for removing rust and scales from forgings, castings, welded joints and heat treated parts. The methods used are abrasive blast cleaning, tumbling, barrel rolling, power brushing and mechanical polishing or buffing.

Finishing of Metals

The main methods of finishing metals are :

1. Metallic coatings
2. Plastic coatings
3. Organic finishes
4. Inorganic finishes

Metallic Coatings

Generally applied by electroplating, hot dipping such as galvanizing, calorizing, phosphate coating, anodising and metallizing. (Spraying of molten metals)

Metallic coatings are used to provide a decorative finish, protection against corrosion and resistance to wear. They also serve as base for painting and to provide thermally and electrically conductive surfaces.

Metallic coating is done by:
- Electro plating
- Hot dipping
- Galvanising
- Tin coating
- Parkerizing
- Anodising
- Metallizing.

(i) ***Electroplating*** may be described as a process of covering a surface or object (usually metallic) with a thin adherent coating of the same or other metal by electrolysis process.

(ii) ***Hot dipping*** is a rapid, inexpensive process which forms a coating of corrosion-resistant metals on base metals by dipping in molten bath. The various kinds of coating given by hot dipping process are zinc coating on iron and steel and also tin, lead and aluminium coatings on steel, copper and cast iron.

(iii) ***Galvanizing*** is a commercial term used for the process by which zinc coating is produced on iron or low-carbon steel by immersion in molten bath of zinc.

(iv) ***Tin coating*** is usually applied to sheet steel by hot dipping or by electroplating process.

(v) ***Calorising*** is the commercial name for the cementation of metal surfaces with aluminium. This process is used to protect iron from oxidation at elevated temperatures.

(vi) ***Phosphate coating*** or **parkerizing** is a process for coating the base metal with a thin phosphate coating which serves as a base or primer before painting or enamelling process on iron and steel.

(vii) ***Anodising*** is an electrochemical process which improves the appearance and provides an anti corrosion protection to parts made of aluminium.

(viii) ***Metal spraying*** or **metallizing** means to treat with, especially to coat with a metal, to impregnate with a metal or a metal compound. Metallizing is the term used to designate the process of metal spraying. Metallizing includes the preparation of the base metal, the spraying of the molten metal on the base metal and the finishing of the coated surface by grinding.

Plastic Coatings

Metal surfaces can be coated with plastic to protect them from corrosion. Chemical plant equipments, electroplating tanks, pipe lines, valve bodies which are exposed to corrosive environment are coated with plastic. Normally used plastic coatings are PVC, Nylon, Polythene, Polytetra fluro ethylene (p-t-f-e).

Organic Finishes

Organic finishing consists of coating a surface with a continuous film of an organic film (film-forming) forming material such as paints, enamels, varnishes, lacquer, etc.

Inorganic Finishes

Inorganic coatings are made up of refractory compounds. They include porcelain enamels and ceramic coatings composed of inorganic mineral materials which are fused to these metals. They can be applied to both ferrous and non-ferrous surfaces.

MANUFACTURING OPERATIONS AS CONVERSION PROCESSES

Manufacturing operations are used to convert or transform inputs into outputs (*i.e.*, raw materials into finished goods). In general conversions or transformations may effect a chemical change, alter the basic shape or form, add or subtract parts as in assembly and also include supporting operations such as inspection, transportation and information/communication operations. In manufacturing industries, there are experts or professionals (*for example* engineers – mechanical, chemical industrial or production engineers) in the process or technology in a wide variety of fields. These experts have knowledge about alternate ways of accomplishing the desired manufacturing operations.

In mechanical industries, metal machining of basic shapes of industrial metals (such as steel, aluminum, brass, copper etc.) and forging and castings is accomplished through basic machine tool processes which involve generation of cylindrical surfaces, (turning operation), flat surfaces (milling, shaping or planing operations) curved surfaces (milling) and holes (drilling operation). There are a number of different types of machine tools to accomplish these various generalized tasks, depending on size and shape of the part to be machined, the quality of surface finish required, accuracy (*i.e.*, tolerance on dimensions) required and the rate of output demanded in various manufacturing situations. In modern manufacturing practices, many of the machine tool operations have been automated through a process which combines computer instructions to the machine and are known as ***numerically controlled processes***.

CHARACTERISTICS OF MODERN MANUFACTURING

(i) Specialisation

Specialisation means the division of work or effort and this operates both at the worker level and management level. At the worker level, individual worker works in trades requiring a great deal of skill such as machinist, tool and die makers, welders, painters etc. Other workers do special semi-skilled jobs. Both skilled and semiskilled specialists are engaged in manufacture of a single product in large volumes (*i.e.* mass production). The result of such specialisation is low cost of production and improved quality. At the management level, management effort is divided into various special functions such as research and development, design, engineering, finance, accounting, sales, purchase, personnel, maintenance etc.

(ii) Mechanisation

Mechanisation replaces human labour (muscle power) by machine power (mechanical power). The human skill is transferred to machine tools which carryout various manufacturing operations. Advanced form of Mechanisation is known as ***automation.***

(iii) Use of Technology of Industrial Engineering

Industrial engineers have been able to devise improvements and to increase productivity by elimination of waste and inefficiency, thereby increasing production and reducing costs.

(iv) Increasing use of Computers and Data Processing Equipments

Widespread use of computers in manufacturing industries has made possible, the handling of enormous amounts of data and the solving of complex mathematical problems at high speed. The range of application of computers include product design, control of manufacturing process, production and inventory control, quality control, maintenance control, inspection, accounting and pay rolls etc.

(v) Use of the Scientific Method

Industrial engineering, operations research or management science involve quantitative (or scientific) methods and techniques to solve both engineering and managerial problems. Operations research is an aid in decision making based on quantitative analysis.

I OPERATIONS IN THE SERVICE SECTOR

Services are those economic activities which typically produce an intangible product.

Services are those economic activities, which typically produce an intangible product such as education, entertainment, hospitality, government, financial, transportation and health services. The service sector includes repair and maintenance, food and lodging, tourism, transportation, telecommunication, banking and insurance, trade, financial, real estate, education, legal, medical and health services, entertainment, government and other professional occupations.

Services have increasingly assumed an important role in the economic development of many countries, including India. Almost all developed countries and many developing countries are emerging as service economies with the service sector contributing to more than 50 percent of the gross domestic product of those countries. Services are becoming a critical source of wealth in many ways to the economies. Service industries also account for most of the growth in new jobs. Many countries are shifting from a manufacturing based economy to a service economy. The present age is an information age spurred by the inventions of the computer and advancement in telecommunications. As countries continue to shift from an agricultural and industrialised economic base, the demand for services will continue to increase. Advances in product technology have led to a rise in the demand for services, especially in maintenance services. Also cultural and social changes have occurred in many societies causing a change in the attitude of individuals toward services.

As the world moved toward a global economy, the service sector has become a very significant contributor. *"Any major economy that is not competitive in the services sector is not competitive internationally"*. Many industrialised nations export more services than manufactured goods.

Services Versus Goods

Services differ from goods in several ways:

(i) Services are ***usually intangible*** as compared to a tangible good.

(ii) *Services* are ***often produced and consumed simultaneously,*** there is no stored inventory of services.

(iii) Services are ***often unique***, *for example* investments and insurance policies of individual customers.

(iv) Services have ***high customer interaction.*** Services are often difficult to standardise, automate and customer interaction demands uniqueness in the services desired by customers.

(v) Services have ***inconsistent product definition***.

(vi) Services are ***often knowledge based*** e.g., educational, medical and legal services.

(vii) Services are **frequently *dispersed***, because many services may have to be frequently brought to the client customer.

Differences between goods and services are summarised in the table shown below:

Table 4.2 : Difference between Goods and Services

Goods (Tangible Products)	Services (Intangible Products)
(i) Goods can be resold.	(i) Reselling services in unusual.
(ii) Goods can be inventoried.	(ii) Many services can not be inventoried.
(iii) Some aspects of quality are measurable.	(iii) Many aspects of quality are difficult to measure.
(iv) Selling is distinct from production of goods.	(iv) Selling is often a part of the production of service.
(v) Goods are transportable.	(v) Service provider, not the service itself is often transportable.
(vi) Location of facility is important for cost.	(vi) Location of facility is not important.
(vii) Often easy to automate production of goods.	(vii) Service is often difficult to automate.
(viii) Revenue is generated primarily from the tangible goods even if they are accompanied by services.	(viii) Revenue is generated primarily from the intangible services even though there are some goods which are associated with services.

However, it may be noted that a clear cut distinction between goods and services is difficult to make. In reality, all services are a mixture of a service and a tangible good. Also the sale of many goods includes or requires service, *for example*, automobile sales has the service components of financing and transportation. Many tangible goods, such as office equipments, computers etc. also require after-sales-training and maintenance services. When a tangible product is not included in the services, such a service is called as a **"Pure Service"**, *for example*, counseling, baby sitting etc., However, there are not many pure services.

Primary Characteristics of Services

Four primary characteristics of services are:
- **Intangibility**
- **Perishability**
- **Inseparability**
- **Variability.**

Services posses four primary inherent characteristics not found in goods. These characteristics are:

(i) **Intangibility**, (ii) **Perishability**, (iii) **inseparability** and (iv) **variability.**

Although not all services possess all of these characteristics, they do exhibit most of them and some others that are the consequences of them. The discussion about these characteristics of services will provide some insight into the unique problems managers of service operations encounter.

(i) Intangibility

Most services are *intangible*. Tangible goods can be seen, touched, smelled, heard or tasted prior to purchase unlike services. Most services are *performances*. Services vary in the degree to which they are intangible. Services such as college education, air travel, and sporting events are highly intangible. The services can not be seen, touched, smelled, heard or tasted

prior to purchase. Services can only be experienced after purchase. However some services have tangible items which are used to perform the service, for example, in college education, there are physical structures such as the buildings, and class rooms, furnitures and teaching aids which can be seen during the visit to the college campus. For air travel, customers can see airplanes, which will be used to transport them to their distinations.

Intangibility: Services cannot be seen, touched, smelt, heard or tasted unlike goods.

An important consequence of intangibility is that for most services, purchasing the service does not result in ownership, whereas purchasing of goods implies ownership. Other problems caused by intangibility of services are :

(a) lack of ability to be stored.

(b) lack of protection by patents.

(c) difficulty in displaying or communicating services.

(d) difficulty in pricing services.

(ii) Perishability

Perishability of a service means the service can not be inventoried or stored. Most services, because they are simultaneously produced and consumed are considered perishable. *For example*, hotel rooms, seats on an airplane or in a movie theatre can not be stored and retrieved for later use. Because of the nature of perishability, a service firm may have to cope with fluctuating demand. It requires that service managers allocate service capacity carefully and attempt to actively manage service demand. To reduce the negative impact of perishability, it is necessary to make simultaneous adjustments in demand, supply and capacity. At the optimum, demand will equal supply and supply will equal capacity.

Perishability: Services can not be stored or inventoried.

(iii) Inspearabilty

Inseparability refers to the simultaneous production and consumption of services. Goods can be produced and then sold later whereas services can not. They can be consumed only when they are produced. Inseparability refers to (a) the service provider's physical connection to the service being provided, (b) the customer's involvement in the service production process and (c) the involvement of other customers in the service production process.

Inseparibility: Services are produced and consumed simultaneously.

Because a service must be performed and consumed at the same time, the quality of the service is highly dependent on the ability of the service provider and the quality of the interaction between the service provider and the customer.

(iv) Variability

Variability refers to the unwanted or random levels of service quality customers receive when they patronise a service because of the human element involved in providing a service. Various service employees will perform the same service differently and even the same service employee will provide varying levels of service from one time to another. Because of the variability characteristic of services, standardisation and quality control are more difficult. This characteristic of variability is also called as ***"heterogeneity"***. Problems due to variability characteristic of services can be reduced by (a) customising the service to meet each customer's exact specifications and (b) standardising the service through intensive training of service providers and/or (c) replacing human labour with machines or automation.

Variability: Customers receive unwanted or random levels of service quality because of the human element involved in providing a service.

I PRODUCTION OF GOODS (MANUFACTURING) VERSUS SERVICE OPERATIONS

Production of goods results in tangible output, whereas service operation implies an act or *performance* which will result in intangible, perishable products.

Manufacturing and service are often similar in terms of *what* is done but different in terms of *how* it is done. For example, both involve design and operating decisions. Both involve decisions regarding facilities needed, location of the facilities, schedule and control operations and allocation of scarce resources.

Manufacturing and service organisations differ in the following:

1. Customer contact, 2. Uniformity of input, 3. labour content of jobs, 4. uniformity of output, 5. location of facility, 6. measurement of productivity, 7. simultaneous production and delivery/consumption and 8. quality assurance.

These differences are discussed in detail in the following paragraphs:

Manufacturing and service organisations differ in the following:
- **Customer contract**
- **Uniformity of input**
- **Labour content of jobs**
- **Uniformity of output**
- **Location of facility**
- **Measurement of productivity**
- **Simultaneous production and delivery\ consumption**
- **Quality assurance.**

1. Often services involve a much higher degree of customer contact than manufacturing. Most customers for manufactured goods have little or no contact with the production system. However in many service organisations, customers themselves are inputs and active participants in the process. On the other hand, manufacturing allows a separation between production and consumption, so that manufacturing can occur away from the consumer. This permits a fair degree of flexibility in selecting work methods, assigning jobs, scheduling work and exercising control over operations. In service operations, the service providers are in direct contact with customers and have a limited range of option. Also, sometimes, customers are part of the service system (*e.g.,* self service operations) and hence tight control is impossible. In addition product oriented operations can build up inventories of finished goods which can be helpful to meet varying demands. Service operations can not build up inventories of *service time* and are more sensitive to demand variability.
2. Service operations are subject to greater variability of inputs than manufacturing operations (*e.g.,* patients, automobile for repair, client for lawyers etc.).
3. Services often require a higher labour content whereas manufacturing can be mechanised (*i.e.,* more capital intensive).
4. Variability in output is less in manufacturing of goods because of high mechanisation or automation (eliminating human errors) whereas service output is more variable due to human element in the service operations (except in case of automated services such as ATM booths etc.).
5. Another distinction is in terms of location and size of an operation. Manufacturing facilities often serve regional, national or international markets and require larger facilities, more automation and greater capital investment than for service facilities. Service organisations requiring direct contact with customers must be located relatively nearer their customers.
6. Measurement of productivity is straightforward in manufacturing due to high degree of uniformity of most manufactured items. In case of service operations, variations in demand intensity and variations in requirements from job to job make productivity measurement more difficult as compared to manufacturing.
7. In many cases, customers receive the service as it is performed (*i.e.,* simultaneous production and consumption of service) unlike in case of manufacturing where there is a time gap.
8. Quality assurance is more challenging in services when production and consumption occur simultaneously. Also higher variability of input in services affects quality of output. In case of a manufacturing system, variability in inputs can be controlled and defects in outputs can be corrected before the customer receives the output.

Similarities Between Manufacturing and Services

Despite many differences, there are some similarities between manufacturing and service operations, which are compelling. The similarities are:

1. Manufacturing firms do not just produce goods and service firms do not just offer services. Both types of organisations normally provide a package of goods and services. For example, customers expect both good service and good food at a restaurant and both good service and quality goods from a retailer.
2. Even though service providers can not inventory their outputs, they must inventory the inputs for their service outputs. *For example,* hospitals must maintain an adequate supply of medications, appropriate strength of doctors, nurses and supporting staff.
3. As for customer contact, there are some services, which have little outside customer contact such as the back-room operations of a bank or the baggage handling area at an airport.

From the above discussions regarding differences and similarities between manufacturing and services, it is clearly evident that operations management is relevant to both manufacturing and service operations.

I THE CHALLENGES FACING OPERATIONS MANAGERS:

The key challenges facing service operations managers are:

(i) Managing multiple customers
(ii) Understanding the service concept
(iii) Managing the outcome and experience
(iv) Managing in real-time
(v) Knowing, implementing and influencing strategy
(vi) Continually improving operations
(vii) Encouraging innovation
(viii) Managing short-term and long-term issues simultaneously

These are briefly explained in the following paragraphs:

Managing Multiple Customers: Many service organizations often serve heterogeneous group of customers, in different ways and different types of customers. Understanding who are the carious customers, understanding their needs and expectations, developing relationships with them and managing the various customers are key tasks for service operations managers.

Understanding the Service Concept: There may be differing views about what service an organization is selling and/or the customer is buying. Articulating and communicating the service concept is critical for classifying the organisation's service product to all its customers and for ensuring that it can be delivered to customer specification.

Managing the Outcome and Experience: For many services, there is no clear boundary between experience and the outcome, for example, customers in a restaurant are buying both the meal and the way they are served. The intangible nature of the experience provides particular problems for both specifications and control. Some organizations try to mange the intangible parts of the service by attempting to make them more tangible.

Managing in Real-Time: Many services happen in real-time. They cannot be delayed or put-off. For example, aircrafts coming into land cannot be put on hold while controllers take a break. Also, during a service encounter it is not possible to undo what is done. In manufacturing operations it is possible to scrap defective products and remake them, but in service operations it is not possible to undo defective service rendered to a customer. For example, a wrong surgery done on a patient may kill the patient. Managing resources, managing staff, and employees and creating an appropriate culture are key tasks in managing real-time services.

Knowing, Implementing and Influencing Strategy: Operations which are the "doing" part of the business are aslo responsible for implementing the strategy of the service

organization. Service operations managers must understand their role, not only in implementing strategy but also in contributing to it or influencing the strategy. Service operations managers need to provide the platform for their organizations for competitive advantage through competence in service operations.

Continually Improving Operations: Service operations managers are faced with a challenge of how continually to improve and develop their real improvements. They should manage the increased complexity resulting from change and also improve efficiency as well as quality of service operations.

Encouraging Innovations: Innovation looks for what is new rather than improving the existing service operations. Therefore, innovations usually require an element of risk- financial risk because innovations require time and money, and personal risk for service managers who champion change putting their reputation on the line. Service operation managers should be alert to, and seek out new ideas and also have the will and support to assess them carefully and follow through if appropriate.

Managing Short-term and Long-term Issues Simultaneously: Organisations are under pressure to perform in the short-term which leaves little time for medium-term operational improvement or long-term strategic planning. Many service operations managers focus their time and effort on managing day-to-day operations to ensure the delivery of an appropriate quality of service at an appropriate cost. As a result, the development and strategic aspects of service operations management are frequently neglected. Service operations managers must pay attention to both strategy and detail of process and resource management to create and sustain a successful service organization.

QUESTIONS

1. Distinguish between manufacturing operations and service operations.
2. How are manufacturing processes classified?
3. Define the term 'Heat Treatment' and state its purposes.
4. Distinguish between annealing and normalising.
5. What is 'hardening' process? What are its requirements? Why 'tempering' is done after hardening process?
6. What are the various methods used in case hardening? What are their advantages?
7. What do you understand by the term 'surface treatment'?
8. Distinguish between electroplating and hot dipping process.
9. Differentiate between 'fabrication' process and 'metal working' process.
10. What is grinding process? Why it is used?
11. What do you mean by 'forming' processes? Give examples.
12. What is anodising process? Why it is used?
13. Discuss the role of manufacturing operations in conversion processes
14. Discuss the characteristics of modern manufacturing.
15. Discuss the importance of service industries for the development of the economy of a country.
16. Discuss the differences and similarities between manufacturing operations and service operations.
17. Describe the primary characteristics of services.
18. Distinguish between goods and services.
19. Briefly discuss the challenges facing service operations managers.

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