CHAPTER | FIVE

Design of Production Systems

Learning Objectives

After reading this chapter, you should be able to:

- Define the terms "product design", "process design" and "production design".
- Know the objectives of production design.
- Discuss the factors influencing product design
- Describe the characteristics of product design.
- Discuss the various approaches to product design.
- Understand the meaning of the terms "process", "process planning", "process design" and "process selection".
- Discuss the topics of "process strategy" and "process management".
- Discuss the major process decisions.
- Discuss what is meant by "make or buy decisions" and "make or buy analysis".

Designing new products and getting them to market is the challenge facing manufacturers in industries as diverse as computer chips and potato chips. Whereas computer chip manufacturers need to offer more powerful IC chips for their customers (such as computer manufacturers), food producers need to provide their customers new taste sensation to sustain or enlarge their retail market share.

The competitiveness and profitability of a firm depend partly on the *design* and *quality* of the products and services offered by the firm and also on the *cost* of production. Hence the relationship between product design to process technology and process design is of considerable interest to production managers. The designing and developing products and production processes are key elements in successful production and operations strategies in today's global economy. Also, design of the *productive system* depends largely on the design of the product and services to be produced as well as the design and selection of production processes.

For all companies, whether high tech, low tech or no tech (*i.e.,* degree of technology used) product design plays an important role in the profitability and their very survival.

The essence of any organisation is the product or services it offers. There is an obvious link between product design and the success of the organisation. Those organisations which have well-designed products are more likely to realise their goals than those with poorly designed products. Hence organisations have a vital stake in achieving good product design.

I PRODUCT DESIGN, PROCESS DESIGN AND PRODUCTION DESIGN

Product Design: Concerned with form and function of a product. It refers to the arrangement of elements or parts that collectively form a product.

Product Design : One way for manufacturers to satisfy customers and gain a differential advantage is through product design which refers to *the arrangement of elements that collectively form a good or service.*

Product Design is concerned with the *form* and *function* of a product. *Form design* involves the determination of what a product would look like, *i.e.,* the shape and appearance of the product, what it will be made of (product structure) and how it will be made (process design). *Functional design* deals with what *function* the product will perform and how it performs.

Functional Design is concerned with the first and foremost requirement of a good product *i.e.,* the product should effectively perform the function for which it is developed. *For example,* for a television set, the picture quality (video) and the sound quality (audio) is more important than the appearance of the cabinet in which the picture tube is fixed.

Form Design is concerned with the appearance, and aesthetic considerations and also the size, volume and weight of the product which are secondary to the performance of the product.

Process Design: Concerned with the overall sequence of operations required to achieve the design specification of the product.

Process Design : Process design is concerned with the overall sequences of operations required to achieve the design specifications of the product. It specifies the type of work stations that are to be used, the machines and equipments necessary to carry out the processes to produce the product. The choice of *process technology* (*i.e.,* manual, mechanised or automated technology) and the process design is related to product design because the manufacturing processes must be capable of achieving the product quality (accuracy, tolerances etc.) specified in the product design and also the product must be designed for *producibility.*

Production Design: Concept of designing products from the point of view of producibility.

Production Design : The design of products and services is partially dependent on the production system design and vice versa. A product or service designed in one way may be costly to produce, but it may be somewhat less costly when designed another way. The concept of designing products from the point of view of *producibility* is known as *production design.*

The producibility and minimum possible production cost of a product are established originally by the product designer and the process technology, process design and selection of the productive system are governed by the limitations of the product design. Hence the basic modes of production for products are thought of in the product design stage itself. *This conscious effort to design for producibility and low manufacturing costs is referred to as production design*.

Importance of Product Design

Production or operations strategy is directly influenced by product design for the following reasons:

(i) As products are designed, all the detailed *characteristics of each product* are established.

(ii) Each product characteristic directly affects *how the product can be made* or produced (*i.e.,* process technology and process design) and

(iii) How the product is made determines the *design of the production system* (production design) which is the heart of production and operations strategy.

Further, product design directly affects product quality, production costs and customer satisfaction. Hence, the design of product is crucial to success in today's global competition.

A good product design can improve the **marketability** of a product by making it easier to operate or use, upgrading its quality, improving its appearance, and/or reducing manufacturing costs.

A *distinctive design* may be the only feature that significantly differentiates a product. An **excellent design** includes *usability, aesthetics, reliability, functionality, innovation* and *appropriateness*. An excellent design provides competitive advantage to the manufacturer, by ensuring appropriate quality, reasonable cost and the expected product features. Firms of tomorrow will definitely compete not on price and quality, but on product design.

What Does Product Design Do?

The activities and responsibilities of product design include the following:

(i) Translating customer needs and wants into product and service requirements (marketing).

(ii) Refining existing products (marketing).

(iii) Developing new products (marketing, product design and production).

(iv) Formulating quality goals (quality assurance, production).

(v) Formulating cost targets (accounting).

(vi) Constructing and testing prototype (marketing, production).

(vii) Documenting specifications (product design).

Reasons for Product Design or Redesign

The most obvious reason for product design is to offer new products to remain competitive in the market. The second most important reason is to make the business grow and increase profits. Also, when productivity gains result in reduction of workforce, developing new products can mean adding jobs and retaining surplus workforce instead of downsizing by layoffs/retrenchment.

Sometimes product design is actually redesign or modification of existing design instead of an entirely new design. The reasons for this include customer complaints, accidents or injuries during product use, excessive warranty claims or low demand. Sometimes product redesign is initiated to achieve cost reductions in labour and material costs.

Objectives of Product Design

(i) The overall objective is profit generation in the long run.

(ii) To achieve the desired product quality.

(iii) To reduce the development time and cost to the minimum.

(iv) To reduce the cost of the product.

(v) To ensure producibility or manufacturability (design for manufacturing and assembly).

FACTORS INFLUENCING PRODUCT DESIGN

(i) **Customer requirements :** The designers must find out the exact requirements of the customers to ensure that the products suit the convenience of customers for use. The products must be designed to be used in all kinds of conditions.

(ii) **Convenience of the operator or user :** The industrial products such as machines and tools should be so designed that they are convenient and comfortable to operate or use.

(iii) **Trade off between function and form :** The design should combine both performance and aesthetics or appearance with a proper balance between the two.

(iv) **Types of materials used :** Discovery of new and better materials can improve the product design. Designers keep in touch with the latest developments taking place in the field of materials and components and make use of improved materials and components in their product designs.

(v) **Work methods and equipments :** Designers must keep abreast of improvements in work methods, processes and equipments and design the products to make use of the latest technology and manufacturing processes to achieve reduction in costs.

(vi) **Cost/Price ratio :** In a competitive market, there is lot of pressure on designers to design products which are cost effective because cost and quality are inbuilt in the design. With a constraint on the upper limit on cost of producing products, the designer must ensure cost effective designs.

(vii) **Product quality :** The product quality partly depends on quality of design and partly on quality of conformance. The quality policy of the firm provides the necessary guidelines for the designers regarding the extent to which quality should be built in the design stage itself by deciding the appropriate design specifications and tolerances.

(viii) **Process capability :** The product design should take into consideration the quality of conformance, *i.e.*, the degree to which quality of design is achieved in manufacturing. This depends on the process capability of the machines and equipments. However, the designer should have the knowledge of the capability of the manufacturing facilities and specify tolerances which can be achieved by the available machines and equipments.

(ix) **Effect on existing products :** New product designs while replacing existing product designs, must take into consideration the use of standard parts and components, existing manufacturing and distribution strategies and blending of new manufacturing technology with the existing one so that the costs of implementing the changes are kept to the minimum.

(x) **Packaging :** Packaging is an essential part of a product and packaging design and product design go hand in hand with equal importance. Packaging design must take into account the objectives of packaging such as protection and promotion of the product. Attractive packaging enhances the sales appeal of products in case of consumer products (non-durable).

Characteristics of Good Product Design

A good product design must ensure the following:

(i) **Function or performance :** The function or performance is what the customer expects the product to do to solve his/her problem or offer certain benefits leading to satisfaction. *For example,* a customer for a motor bike expects the bike to start with a few kicks on the kick peddle and also expects some other functional aspects such as pick-up, maximum speed, engine power and fuel consumption etc.

(ii) **Appearance or aesthetics :** This includes the style, colour, look, feel, etc. which appeals to the human sense and adds value to the product.

(iii) **Reliability :** This refers to the length of time a product can be used before it fails. In other words, reliability is the probability that a product will function for a specific time period without failure.

(iv) **Maintainability :** Refers to the restoration of a product once it has failed. High degree of maintainability is desired so that the product can be restored (repaired) to be used within a short time after it breaks down. This is also known as **serviceability**.

(v) **Availability :** This refers to the continuity of service to the customer. A product is available for use when it is in an operational state. Availability is a combination of reliability and maintainability. High reliability and maintainability ensures high availability.

(vi) **Producibility :** This refers to the ease of manufacture with minimum cost (economic production). This is ensured in product design by proper specification of tolerances, use of materials that can be easily processed and also use of economical processes and equipments to produce the product quickly and at a cheaper cost.

(vii) **Simplification :** This refers to the elimination of the complex features so that the intended function is performed with reduced costs, higher quality or more customer satisfaction. A simplified design has fewer parts which can be manufactured and assembled with less time and cost.

(viii) **Standardisation :** Refers to the design activity that reduces variety among a group of products or parts. *For example,* group technology items have standardised design which calls for similar manufacturing process steps to be followed. Standard designs lead to variety reduction and results in economies of scale due to high volume of production of standard products. However, standardised designs may lead to reduced choices for customers.

(ix) **Specification :** A specification is a detailed description of a material, part or product, including physical measures such as dimensions, volume, weight, surface finish etc. These specifications indicate tolerances on physical measures which provide production department with precise information about the characteristics of products to be produced and the processes and production equipments to be used to achieve the specified tolerances (acceptable variations).

Interchangeability of parts in products produced in large volumes (mass production and flow-line production) is provided by appropriate specification of tolerances to facilitate the desired fit between parts which are assembled together.

(x) **Safety :** The product must be safe to the user and should not cause any accident while using or should not cause any health hazard to the user. Safety in storage, handling and usage must be ensured by the designer and a proper package has to be provided to avoid damage during transportation and storage of the product. *For example,* a pharmaceutical product while used by the patient, should not cause some other side effect threatening the user.

I APPROACHES TO PRODUCT DESIGN

Quality Function Deployment: An approach to product design by which the voice of the customer is incorporated in the product design.

House of quality: A matrix showing the relationship between the customer's requirements and the technical characteristics of the product.

Concurrent engineering: bringing design and manufacturing people together early in the design phase to simultaneously develop the product and processes.

(i) Designing for the customer

Designing for aesthetics and for the user is generally termed **industrial design** which is probably the most neglected area by manufacturers. In many products we use, parts are inaccessible, operation is too complicated or there is no logic to setting and controlling the function of the product. Sometimes worst conditions exist, metal edges are sharp and consumers cut their hands trying to reach for adjustment or repairs. Many products have too many features-far more than necessary and for instance many electronic products have too many features which the customers cannot fully make use of (operate). One approach to getting the **voice of the customer** into the design specification of a product is ***quality function deployment (QFD)***. This approach uses interfunctional teams from marketing, design engineering and manufacturing to incorporate the features sought by the customers in the product at the stage of product design. The customer's requirements (with its importance weightage) and the technical characteristics of the product are related to each other in a matrix called **house of quality**. The customers are asked to compare the company's products to the competitor's products. The technical characteristics are then evaluated to support or refute the customer perception of the product. This data is then used to evaluate the strengths and weaknesses of the product in terms of technical characteristics.

(ii) Designing for Manufacture and Assembly (DFMA)

Traditionally the attitude of designers has been *"we design it, you build it"* which is termed as ***"over-the-wall approach"***, where the designer is sitting on one side of the wall and throwing the design over the wall to the manufacturing engineers. The manufacturing engineers have to deal with the problems that arise because they were not involved in the design effort. This problem can be overcome by an approach known as ***concurrent engineering*** (or simultaneous engineering). Concurrent engineering means bringing design and manufacturing people together early in the design phase to simultaneously develop the product and processes for manufacturing the product. Recently this concept has been enlarged to include manufacturing personnel, design personnel, marketing and purchasing personnel in loosely integrated cross-functional teams. In addition, the views of suppliers and customers are also sought frequently. This will result in product designs that will reflect customer wants as well as manufacturing capabilities in the design stage itself. **Design for Manufacturing (DFM)** and **Design for Assembly (DFA)** are related concepts in manufacturing. The term design for manufacturing is used to indicate the designing of products that are compatible with an organisation's capability. Design for assembly focuses on reducing the number of parts in a product or on assembly methods and sequence that will be employed. Designing for manufacture includes the following guidelines:

(a) Designing for minimum number of parts.

(b) Developing modular design.

(c) Designing for minimum part variations (*i.e.*, communisation or using standardised parts) and

(d) Designing parts for ease of fabrication.

(iii) Designing for ease of production (or for producibility or manufacturability)

Manufacturability or **producibility** is a key concern for manufacturing products. Ease of fabrication and/or assembly is important for cost, productivity and quality. Designing products for ease of production is a key way for manufacturers to be competitive in the world market.

Three concepts which are closely associated to designing for ease of production are: *(a)* specifications, *(b)* standardisation and *(c)* simplification. These concepts are discussed in the following paragraphs:

A **specification** is a detailed description of a material, part or product, including physical measures such as dimensions, volume, weight etc. These physical measure are given tolerances (acceptable variations). Tolerances are stated minimum and maximum for each dimension of a product. Tight tolerances facilitate interchangeability of parts and allows ease of assembly and effective functioning of the finished products.

Standardisation refers to design activity that reduces variety among a group of products or parts. This will result in higher volume for each product or part model which can lead to lower production costs, higher product quality and lower inventory and higher ease of automation.

Simplification of product design is the elimination of complex features so that the intended function is performed with reduced costs, higher quality and better customer satisfaction. Simplified design provides products to customers which can be easily installed, maintained and used by them. Also production costs can be reduced through easier assembly, less expensive substitute materials and less waste or scrap during production.

***(iv)* Designing for Quality**

Building product quality into the product design is the first step in producing products of superior quality. This is known as **"quality of design"** which is followed by **"quality of conformance."** Quality of design refers to the quality specifications incorporated in the design. It consists of quality characteristics such as appearance, life, safety, maintenance and other features of the product. Quality of conformance is the degree to which the product actually conforms to the design specification. Designing products for quality consists of three aspects of design— *(a)* robust design, *(b)* design for production and *(c)* design for reliability which are discussed in the following paragraphs:

(a) **Designing for robustness (or robust design) :** Customers expect products to perform satisfactorily when used in all kinds of field conditions. Hence it is not enough if the products perform as intended when they are produced and used under ideal conditions. A robust design is one that will perform as intended even if undesirable conditions occur either in production or in the field. Robustness can be designed into products by assuming less than desirable field conditions in terms of heat, cold, humidity, nature of use, vibration and other conditions.

(b) **Designing for production** (*i.e.,* for ease of manufacturer and assembly) was discussed in the previous section. This can reduce the sources of error and improve overall product quality. **Modular design** and **designing for automation** are two aspects of designing for ease of production.

(i) ***Modular design*** is the creation of products from some combination of basic, prexisting subsystems known as **modules**. In this approach, products are designed in easily segmented components or modules. This design offers flexibility to both production (manufacture and assembly) and marketing. The modular design concept gives consumers a range of product options and offers considerable advantages in manufacturing and product design. Stabilising the designs of the modules makes them easier to build. Even the maintenance or repair of products in case of break down becomes easier because the faulty module can be easily removed and replaced by a spare module.

(ii) ***Designing for automation* :** In designing for automation, three broad issues affecting product design efforts come into play. They are: *(i)* wasteful or unnecessary processes

should not be automated, *(ii)* simplify the design before automation, *(iii)* the process may be simplified to such an extent that automation may not be needed.

(c) **Designing for reliability :** Reliability is a measure of the ability of a product, part or system to perform its intended function under a prescribed set of conditions. It is the probability that an item will function as planned over a given time period. Reliability is always specified with respect to **normal operating conditions** which are taken into consideration while designing the product for reliability. Reliability of a product can be improved by improving the reliability of the components used in the product, by reducing the number of components used and using backups in case certain components fail in operation. These steps will improve the product design (or system design) and improve the product or system reliability. Other methods of improving reliability are improving production, and/or assembly techniques, improving testing methods, improving preventive maintenance procedures, improving user education etc.

(v) Designing for Ergonomics

Poorly designed products may cause work-related accidents resulting in injuries to users. Hence, comfort, safety and ease of use for the users are becoming more important quality dimensions that have to be considered in product design. **Human factor engineering** or **Ergonomics** applies knowledge of human capabilities and limitations to the design of products and processes.

(vi) Designing for environmental protection

This includes designing products which are environmental friendly (*e.g.*, Euro II automobile) known as **green designs**. Sometimes reaction to a social or environmental concern opens up a set of promising new design options.

A new approach called **"universal design"** is an example of product design in which an attempt is made to design products that are easily operable by disabled persons.

(vii) Designing for recycling

This approach to product design focuses on designing products so that raw materials such as plastics can be retrieved once the product has finished its useful life and scrapped. Recycling means recovering materials for further use. Recycling is done to achieve cost savings, and also to meet environmental concerns and regulations. Designing for recycling facilitates the recovery of materials and components in used products for reuse.

(viii) Designing of disassembly (DFD)

This involves designing products which can be more easily taken apart or disassembled. It includes fewer parts and less material and using snap-fits where possible instead of screws, bolts and nuts.

(ix) Designing for mass customisation

It is a strategy of designing standardised products but incorporating some degree of customisation in the final product. **Delayed differentiation** and **modular designs** are two tactics used to make mass customisation possible.

Delayed differentiation is the process of producing but not quite completing, a product, postponing completion until customer preferences or specifications are known. Modular design is a form of standardisation in which component parts are grouped into modules that are easily replaced or interchanged to produce varieties of the same basic product. One example is a computer system in which a customer can choose a particular configuration depending on the computing, capability desired by the customer. Modular design help mass customisation.

(x) Other issues in product design are *(a)* **Computer aided design (CAD)**, *(b)* **Value engineering or value analysis** which are discussed below:

(a) **Computer aided design :** Computers are increasingly used for product design. CAD uses computer graphics for product design. The designers can modify an existing design or create a new design on a computer monitor screen by means of a keyboard or a joy stick. The design can be manoeuvred on the screen, it can be rotated to provide the designer different views of the product, it can be split apart to have a view of the inside and a position of the product can be enlarged for closer view. The printed version of the completed design can be taken and also the design can be stored electronically. A number of products such as printed circuit boards, transformers, automobile parts, aircraft parts etc. can be designed using CAD.

Computer aided design: Use of computer graphics for designing the product helps to generate a number of alternative designs and identify the best alternative which meets the designer's criteria.

CAD increases the productivity of designers from 3 to 10 times and preparing mechanical drawings of product or parts and modifying them frequently becomes easier. Also a data base can be created for manufacturing which can supply required information on product geometry and dimensions, tolerances, material specifications etc. Also, some CAD systems facilitate engineering and cost analyses on proposed designs, *for example,* calculation of volume and weight and also stress analysis can be done using CAD systems. It is possible to generate a number of alternative designs using computer aided design systems and identify the best alternative which meets the designer's criteria.

(b) **Value engineering/Value analysis in product design :** Value engineering or value analysis is concerned with the improvement of design and specifications at various stages such as research, development, design and product development. Benefits of value engineering are:

Value engineering/ Value analysis: Concerned with the improvement of design and specifications at various stages of product planning and development.

(i) Cost reduction.

(ii) Less complex products.

(iii) Use of standard parts/components.

(iv) Improvement in functions of the product.

(v) Better job design and job safety.

(vi) Better maintainability and serviceability.

(vii) Robust design.

Value engineering aims at cost reduction at equivalent performance. It can reduce costs to the extent of 15% to 70% without reducing quality. While value engineering focuses on **preproduction** design improvement, value analysis, a related technique seeks improvements during the production process.

LEGAL, ETHICAL AND ENVIRONMENTAL ISSUES IN PRODUCT DESIGN

Designers must consider a wide array of legal and ethical considerations. Any aspect of the product which may cause potential harm to the environment must be considered seriously to avoid such issues. The government regulations regarding pollution control, environment protection, consumer safety etc. must be considered by product designers while designing the products. *For example,* automobile design should take into account emission levels and safety features such as seat belts etc.

Another reason for design improvement is **product liability** which means a manufacturer is liable for any injuries or damages caused by a faulty product because of poor design and workmanship. Hence, it is very important that products are designed to be reasonably free of hazards.

Ethical issues often rise in the design of products and services. Managers must be awar of these issues and designers must adhere to ethical standards. Ethical considerations whil designing the products may result in trade-off decisions. *For example,* it is unethical to releas a software to the market without removing most of the bugs involved in it.

PROCESS PLANNING AND PROCESS DESIGN

At the time of designing and developing a product, due consideration is given for th *manufacturability* or *producibility* of the product using the current process technology an the capability of the firm to manufacture the product. If the firm already has the require technology, the facilities (machines and equipments) and the manufacturing processes, an the firm has sufficient capacity or can acquire the needed capacity to manufacture the product then decision is taken to go ahead with the product design. Otherwise, the design effort may be terminated.

After the final design of the product has been approved and released for production, th production planning and control department takes the responsibility of *process planning* an *process design* for converting the product design into a tangible product. As the process plan are firmly established, the processing time required to carry out the production operations o the equipments and machines selected are estimated. These processing times are compared with the available machine and labour capacities and also against the cost of acquiring new machines and equipments required before a final decision is made to manufacture the product completely inhouse or any parts or sub-assemblies must be outsourced.

WHAT IS A PROCESS?

Process: A process is a sequence of activities that is intended to achieve some result, for example, to create added value for the customers

A *process* is a sequence of activities that is intended to achieve some result, typically to create *added value* for the customers.

A process converts inputs into outputs in a production system. It involves the use of organisation's resources to provide something of *value*. No product can be made and no service can be provided without a process and no process can exist without a product or service.

Processes underlie all work activities and are found in all organisations and in all functions of an organisation. Deciding *what processes to use* is an essential issue in the *design of a production system*. Process decisions involve many different choices in selecting human resources, equipment and machinery, and materials. Process decisions are strategic and can affect an organisation's ability to compete in the long run.

Types of processes : Basically, processes can be categorised as:

(i) *Conversion processes, i.e.,* converting the raw materials into finished products (*for example,* converting iron ore into iron and then to steel). The conversion processes could be metallurgical or chemical or manufacturing or construction processes.

(ii) *Manufacturing processes* can be categorised into *(a)* Forming processes, *(b)* Machining processes and *(c)* Assembly processes.

(iii) *Testing processes* which involve inspection and testing of products (sometimes considered as part of the manufacturing processes).

Forming processes include foundry processes (to produce castings) and other processes such as forging, stamping, embossing and spinning. These processes change the shape of the raw material (a metal) into the shape of the workpiece without removing or adding material.

Machining processes comprise metal removal operations such as turning, milling, drilling, grinding, shaping, planing, boring etc.

Assembly processes involve joining of parts or components to produce assemblies having specific functions. Examples of assembly processes are welding, brazing, soldering, riveting, fastening with bolts and nuts and joining using adhesives.

Process planning: Concerned with planning the conversion processes needed to convert the raw material into finished products.

PROCESS PLANNING

What is process planning? Process planning is concerned with planning the conversion processes needed to convert the raw material into finished products. It consists of two parts: *(i)* ***Process design*** and ***(ii) Operations design***.

Process design: Concerned with the overall sequences of operations required to achieve the product specifications

Process design is concerned with the overall sequences of operations required to achieve the product specifications. It specifies the type of work stations to be used, the machines and equipments necessary to carry out the operations. The sequence of operations are determined by *(a) the nature of the product, (b) the materials used, (c) the quantities to be produced and (d) the existing physical layout of the plant.*

Operations design: Concerned with the design of the individual manufacturing operation.

Operations design is concerned with the design of the individual manufacturing operation. It examines the *man-machine relationship* in the manufacturing process. Operations design must specify how much labour and machine time is required to produce each unit of the product.

Framework for Process Design

The process design is concerned with the following:

(i) Characteristics of the product or service offered to the customers.

(ii) Expected volume of output.

(iii) Kinds of equipments and machines available in the firm.

(iv) Whether equipments and machines should be of special purpose or general purpose.

(v) Cost of equipments and machines needed.

(vi) Kind of labour skills available, amount of labour available and their wage rates.

(vii) Expenditure to be incurred for manufacturing processes.

(viii) Whether the process should be capital-intensive or labour-intensive.

(ix) Make or buy decision.

(x) Method of handling materials economically.

PROCESS SELECTION

Process selection refers to the **way** production of goods or services is organised. It is the basis for decisions regarding capacity planning, facilities (or plant) layout, equipments and design of work systems. Process selection is necessary when a firm takes up production of new products or services to be offered to the customers.

Three primary questions to be addressed before deciding on process selection are:

(i) How much *variety* of products or services will the system need to handle?

(ii) What degree of equipment *flexibility* will be needed?

(iii) What is the expected *volume* of *output*?

I PROCESS STRATEGY

Process strategy: An organisation's approach to selection of the process for the conversion of resource inputs into outputs.

A **process strategy** is an organisation's approach to *process selection* for the purpose of transforming resource inputs into goods and services (outputs). The objective of a process strategy is to find a way to produce goods and services that meet customer requirement and product specification (*i.e.,* design specifications) within the constraints of *cost* and other managerial limitations. The process selected will have a long-term effect on efficiency and production as well as flexibility, cost, and quality of the goods produced. Hence it is necessary that a firm has a sound process strategy at the time of selecting the process.

Make or buy decisions: Refer to the extent to which a firm will produce goods or provide services in-house or go for outsourcing or subcontracting

Key aspects in process strategy include:

(i) Make or buy decisions

(ii) Capital intensity and

(iii) Process flexibility

Make or buy decisions refer to the extent to which a firm will produce goods or provide services *in-house* or go for *outsourcing* (buying or subcontracting). It will be discussed in detail later in this chapter.

Capital intensity: The mix of equipment and labour which will be used by the firm.

Capital intensity refers to the mix of equipment and labour which will be used by the firm.

Process flexibility: The degree to which the system can be adjusted to changes in processing requirements

Process flexibility refers to the degree to which the system can be adjusted to changes in processing requirements due to such factors as changes in product or service design, changes in volume of products produced and changes in technology.

Three process strategies : Virtually every good or service is made by using some variation of one of three process strategies. They are: ***(i)* process focus *(ii)* repetitive focus** and ***(iii)* product focus**.

Exhibit 5.1 illustrates the relationship between the three process strategies and volume and variety of products produced.

Each of these three strategies are discussed below:

Three Process Strategies are:
- **Process Focus**
- **Repetitive Focus**
- **Product Focus**

***(i)* Process focus :** Majority (about 75 per cent) of global production is devoted to *low volume, high variety* products in manufacturing facilities called job shops. Such facilities are organised around performing processes. *For example,* the processes might be welding, grinding or painting carried out in departments devoted to these processes. Such facilities are **process focussed** in terms of equipment, machines, layout and supervision. They provide a high degree of product flexibility as products move intermittently between processes. Each process is designed to perform a wide variety of activities and handle frequent changes. Such processes are called **intermittent processes.** These facilities have high variable costs and low utilisation of facilities.

***(ii)* Repetitive focus :** A repetitive process is a product oriented production process that uses modules. It falls between product focus and process focus. It uses modules which are parts or components prepared often in a continuous or mass production process.

A good example of repetitive process is the **assembly line** which is used for assembling automobiles and household appliances and is less flexible than process-focused facility. Personal computer is an example of a repetitive process using modules in which the modules are assembled to get a custom product with the desired configuration.

(iii)* Product-focus :** It is a facility organised around products, a product oriented, high-volume low-variety process. It is also referred to as ***continuous process because it has very long continuous production run. Examples of product focussed processes are steel, glass, paper, electric bulbs, chemicals and pharmaceutical products, bolts and nuts etc. Product-focussed facilities need standardisation and effective quality control. The specialised nature of the facility requires high fixed cost, but low variable costs reward high facility utilisation.

Exhibit 5.1 : Process Selected Must Fit with Volume and Variety

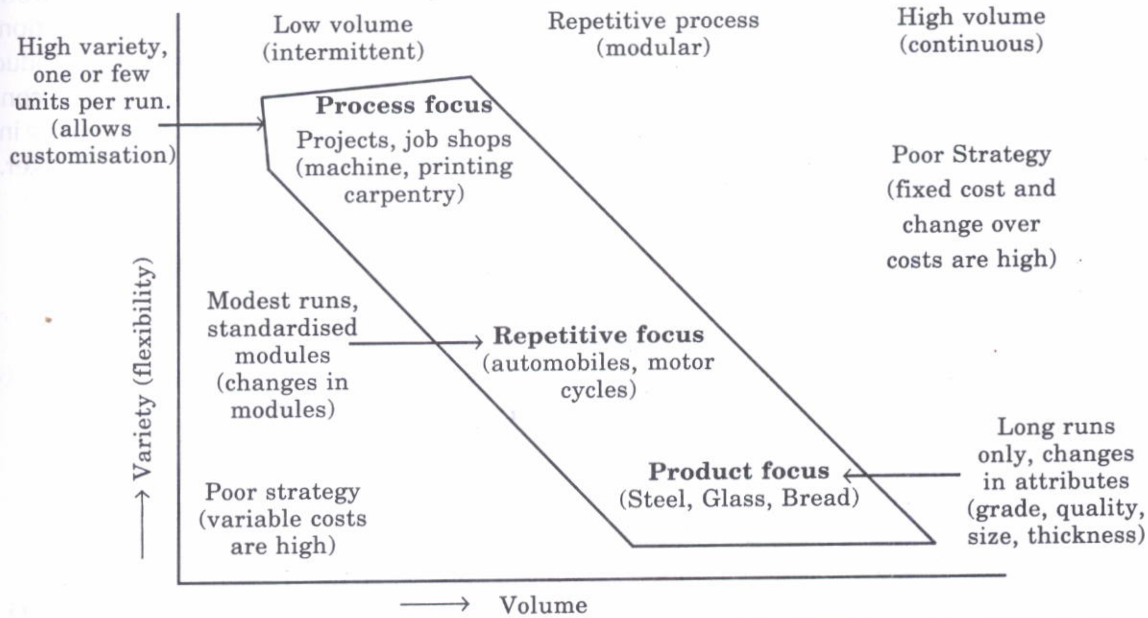


Table 5.1 gives a comparison of three process choices namely process focus, repetitive focus and product focus.

Table 5.1 : Comparison of the Characteristics of Three Types of Process Strategies

Process Focus (Low Volume-High Variety)	Repetitive Focus (Modular)	Product Focus (High Volume-Low Variety)
1. Small quantity and large variety of products are produced	1. Long runs, usually standardised products with options for customers are produced from modules	1. Large quantity and small variety of products are produced
2. General purpose machines and equipments are used	2. Special equipments used in assembly lines	2. Special purpose machines and equipments are used
3. Broadly skilled operators	3. Modestly trained operators	3. Broadly skilled operators
4. Many job instructions because of job changes	4. Repetitive operations reduce job instructions and training	4. Few job instructions because jobs are standardised
5. High raw material inventory	5. Just-in-time procurement techniques are used	5. Low raw material inventories relative to value of output
6. High work-in-process compared to output	6. Just-in-time production techniques are used	6. Work-in-process inventory is low compared to output
7. Work flow is slow	7. Work flow is slow	7. Fast work flow
8. Finished goods are usually made to order and not stored	8. Finished goods are made to frequent forecasts	8. Finished goods are usually mode to a forecast and stored
9. Production scheduling is complicated, concerned with trade-off between inventory availability, capacity and customer service	9. Production scheduling is based on building various models from a variety of modules to forecasts	9. Simple production scheduling, concerned with establishing a rate of output sufficient to meet demand forecast
10. Low fixed costs and high variable costs	10. Fixed costs are dependent on flexibility of the facility	10. Fixed costs tend to be high and variable costs low.

PROCESS MANAGEMENT

Process management: Concerned with the selection of inputs, operations, work flows and methods that transform inputs into outputs.

Process management is concerned with the selection of inputs, operations, work flows and methods that transform inputs into outputs. The starting point of input selection is the make-or-buy decision (*i.e.*, deciding which parts and components are to be produced in-house and which are to be purchased from outside suppliers). Process decisions are concerned with the proper mix of human skills and equipments needed to produce the parts in-house and which part of the processes are to be performed by each equipment and worker.

Process decisions must be made when

(i) a new or modified product or service is being offered

(ii) quality must be improved

(iii) competitive priorities have changed

(iv) demand for a product or service is changing

(v) cost or availability of materials has changed

(vi) competitors are doing better by using a new technology or a new process.

MAJOR PROCESS DECISIONS

Five common process decisions considered by production/operations managers are:

(i) Process choice, *(ii)* Vertical integration, *(iii)* Resource flexibility, *(iv)* Customer involvement and *(v)* Capital intensity.

Five major process decisions considered by POM Managers are:
- **Process choice**
- **Vertical intergration**
- **Resource flexibility**
- **Customer involvement**
- **Capital intensity.**

Process choice determines whether resources are organised around products or processes in order to implement the *flow strategy*. It depends on the volumes and degree of customisation to be provided.

Vertical integration is the degree to which a firm's own production system handles the *entire supply chain* starting from procurement of raw materials to distribution of finished goods.

Resource flexibility is the ease with which equipments and workers can handle a wide variety of products, levels of output, duties and functions.

Customer involvement refers to the ways in which customers become part of the production process and the extent of their participation.

Capital intensity is the mix of equipment and human skills in a production process. Capital intensity will be high if the relative cost of equipment is high when compared to the cost of human labour.

These major process decisions are discussed in detail in the following paragraphs :

1. **Process Choice :** The production manager has to choose from five basic process types — *(i)* job shop, *(ii)* batch, *(iii)* repetitive or assembly line, *(iv)* continuous and *(v)* project.

   (i) Job shop process : It is used in job shops when a low volume of high-variety goods are needed. Processing is *intermittent*, each job requires somewhat different processing requirements. A job shop is characterised by high customisation (made to order), high flexibility of equipment and skilled labour and low volume. A tool and die shop is an example of job shop, where **job process** is carried out to produce one-of-a kind of tools. Firms having job shops often carry out job works for other firms. A job shop uses a flexible flow strategy, with resources organised around the process.

   (ii) Batch process : Batch processing is used when a moderate volume of goods or services is required and also a moderate variety in products or services. A batch process differs from the job process with respect to volume and variety. In batch processing, volumes are higher because same or similar products or services are repeatedly provided, examples of products produced in batches include paint, ice cream, soft drinks, books and magazines.

Process choice: Five basic types of process are:

- Jobshop process
- Batch process
- Repetitive process
- Continuous process
- Project process.

(iii) ***Repetitive process :*** This is used when higher volumes of more standardised goods or services are needed. This type of process is characterised by slight flexibility of equipment (as products are standardised) and generally low labour skills. Products produced include automobiles, home appliances, television sets, computers, toys etc. Repetitive process is also referred to as **line process** as it include **production lines** and **assembly lines** in mass production. Resources are organised around a product or service and materials move in a line flow from one operation to the next according to a fixed sequence with little work-in-progress inventory. This kind of process is suitable to ***"manufacture-to-stock"*** **strategy** with standard products held in finished goods inventory. However, ***"assemble-to-order"*** strategy and ***"mass customisation"*** are also possible in repetitive process.

(iv) ***Continuous process :*** This is used when a very highly standardised product is desired in high volumes. These systems have almost no variety in output and hence there is no need for equipment flexibility. A continuous process is the extreme end of high volume, standardised production with rigid line flows. The process often is capital intensive and operate *round the clock* to maximise equipment utilisation and to avoid expensive shut downs and shut ups. Examples of products made in continuous process systems include petroleum products, steel, sugar, flour, paper, cement, fertilisers etc.

(v) ***Project process :*** It is characterised by high degree of job customisation, the large scope for each project and need for substantial resources to complete the project. Examples of projects are building a shopping centre, a dam, a bridge, construction of a factory, hospital, developing a new product, publishing a new book etc. Projects tend to be complex, take a long time and consist of a large number of complex activities. Equipment flexibility and labour skills can range from low to high depending on the type of projects.

Table 5.2 provides an overview of the processes discussed in this section.

Vertical integration: The amount of the production and distribution chain which is brought under the ownership of a firm.

2. **Vertical Integration :** *Vertical integration* is the amount of the production and distribution chain, from suppliers of components to the delivery of products/services to customers, which is brought under the ownership of a firm. The management decides the level or degree of integration by considering all the activities performed from the acquisition of raw materials to the delivery of finished products to customers. The degree to which a firm decides to be vertically integrated determines how many production processes need to be planned and designed to be carried out in-house and how many by outsourcing. When managers decide to have more vertical integration, there is less outsourcing. The vertical integration is based on **"make-or-buy" decisions**, with **make** decisions meaning more integration and a **buy** decision meaning less integration and more outsourcing. Two directions of vertical integration are *(a)* **Backward integration** which represents moving upstream toward the sources of raw materials and parts, for example a steel mill going for backward integration by owning iron ore and coal mines and a large fleet of transport vehicles to move these raw materials to the steel plant. *(b)* **Forward integration** in which the firm acquires the channel of distribution (such as having its own warehouses, and retail outlets).

The advantages of more vertical integration are disadvantages of more outsourcing and similarly, advantages of more outsourcing are disadvantages of more vertical integration.

Table 5.2 : Types of Processes

Description	Job Shop Process	Batch Process	Repetitive (Assembly) Process	Continuous Process	Project Process
Output characteristics goods & services	Customised goods or services	Semi-standardised goods or services	Standardised goods or services	Highly standardised goods orservices	Highly customised services
Examples of productive systems	Machine shop, tool room	Bakery, class room	Assembly line for automobiles	Steel mill, paper mill	Building bridges and dams
Examples of goods produced	Press tools, moulding tools	Bread, cakes, cookies	Automobiles, Television sets, computers	Steel, paper, sugar, flour	–
Volume	Low	Low to moderate	High	Very high	Very high
Output variety	Very high	Moderate	Low	Very low	Extremely low
Equipment flexibility	Very high	Moderate	Low	Very low	Low to high
Cost Estimation	Difficult	Somewhat routine	Routine	Routine	Complex
Cost per unit	High	Moderate	Low	Low	Very high
Equipment used	General purpose	General purpose	Special purpose	Special purpose	Varied
Fixed costs	Low	Moderate	High	Very high	Varied
Variable costs	High	Moderate	Low	Very low	High
Labour skills	High	Moderate	Low	Low	Low to high
Scheduling	Complex	Moderately complex	Routine	Routine	Complex, subject to change
Work-in-process inventory	High	High	Low	Low	Varied
Advantages	Able to handle a wide variety of work	Flexibility	Low unit cost, high volume, efficient	Very efficient, very high volume	Suitable for non-routine time and cost bound work
Disadvantages	Slow, high cost per unit, complex planning and scheduling	Moderate cost per unit, moderate scheduling complexity	Low flexibility high cost of of downtime	Very rigid, lack of variety, cost to change, very high cost of downtime	Very difficult to plan and control resources cost and time of completion

Advantages of vertical integration are:

(i) Can sometimes increase market share and allow the firm enter foreign markets more easily.

(ii) Can achieve savings in production cost and produce higher quality goods.

(iii) Can achieve more timely delivery.

(iv) Better utilisation of all types of resources.

Disadvantages of vertical integration are:

(i) Not attractive for low volumes.

(ii) High capital investment and operating costs.

(iii) Less ability to react more quickly to changes in customer demands, competitive actions and new techniques.

3. **Resource flexibility :** The choices that management makes concerning competitive priorities determine the degree of flexibility required of a firm's resources — its employees, facilities and equipment. Production managers must decide whether to have **flexible workforce** which will provide reliable customer service and avoid capacity bottlenecks. Flexible workforce is useful with flexible flow strategy to even out fluctuating work loads. Also when volume flexibility is required, instead of laying off and hiring workforce to match varying demands, it is better to have certain amount of permanent workforce having multiple skills. This will facilitate movement of surplus workforce from low-load work centres to higher-load work centres.

   When a firm's product has a short life cycle and a high degree of customisation, low production volumes mean that the firm should select *flexible general purpose machines and equipments*.

Resource flexibility: Means the flexibility of resources such as employees, facilities and equipment.

4. **Customer-involvement** is the extent to which customers interact with the process. A firm which competes on customisation allows customers to come up with their own product specification or even become involved in the designing process for the product (quality function deployment approach to design for incorporating the voice of the customer).

Customer Involvement: The extent to which customers interact with the process.

5. **Capital intensity** means the predominant resource used in manufacturing, *i.e.,* capital equipments and machines rather than labour. Decision regarding the amount of capital investment needed for equipments and machines is important for the design of a new process or the redesign of an existing one. As the capabilities of technology increase (for example automation), costs also will increase and managers have to decide about the extent of automation needed. While one advantage of adding capital intensity is significant increase in product quality and productivity, one big disadvantage can be high investment cost for low-volume operations.

Capital Intensity: Means the predominant resources used in manufacturing consists of machines and equipments rather than human labour.

MAKE-OR-BUY DECISIONS

This is the very first step in process planning. It involves considering whether to make or buy some or all of a product or service. A manufacturing firm might decide to purchase certain parts rather than make them, sometimes the firm may buy all the parts from **outsourcing** and simply perform only assembly operations to produce the finished product. Buy decisions reduce or eliminate the need for process selection.

Make-or-Buy Decisions: The very first step in process planning. involves considering whether to make or buy some or all of a product or service.

Traditionally, the **make** option tended to be favoured by many large firms, resulting in backward integration and ownership of a large range of manufacturing and assembly facilities. Major purchases were mainly confined to raw materials and components which were then processed in-house. But the increased global competition in recent years created pressures to reduce costs, downsizing the workforce and focusing on the firm's *core competencies*. Hence the trend is now toward outsourcing for goods or services that had been previously provided in-house. Make-or-buy decisions pertain to basic questions of specialisation and vertical integration.

At the completion of product design, the design department prepares the product design documents such as product structure tree, part lists, drawings for parts, components, sub-units and final assembly of the product. The process planning engineers are required to make the important decision of make-or-buy, considering a number of factors. Also the required capacity of the firm to produce the finished products depends on the "make" decision.

In make-or-buy decision, the various factors usually considered are:

Factors considered in Make-or-Buy decisions are:

- Available capacity
- Expertise
- Quality
- Nature of demand
- Cost

(i) **Available capacity :** If the firm has available capacity in equipments, necessary skills an time, it makes sense to produce an item so that the available capacity in equipments an skilled labour can be made use of.

(ii) **Expertise :** If the needed expertise is lacking in the firm, buying might be a bette alternative.

(iii) **Quality considerations :** Outside suppliers who specialise can usually offer higher qualit products than what the firm can produce. But unique quality requirement or the desir to closely monitor the quality may cause a firm to decide to "make."

(iv) **The nature of demand :** When the demand for a product is high and stable, it is bette for the firm to produce the item rather than buy. Alternatively, when fluctuations i demand, or small orders have to be handled, it is better to buy the item from multipl sources who are specialists.

(v) **Cost :** Any cost savings achieved from buying or making must be weighed against th preceding factors. Economic analysis of make or buy decision is based on break-even analysis or economic batch quantity or economic order quantity concepts.

Apart from the above important considerations, the other non-economic considerations could be:

(i) Availability of suppliers (for outsourcing).

(ii) Desire to specialise in a particular field of manufacture.

(iii) Control of design secrets.

(iv) Availability of research and development facilities in-house.

(v) Reliability of outside suppliers.

(vi) Lead time for procurement versus lead time for in-house manufacture.

(vii) Delivery schedules to be met.

(viii) Employee preferences for particular nature of work.

Depending on the various considerations discussed above, managers are required to make decisions regarding *(a)* **when to make** and *(b)* **when to buy**.

When to make? Some of the reasons that may lead the managers to decide to make a part or a component or a product in-house instead of buying are:

(i) *Higher purchase price per unit* of the item as compared to the per unit product cost if produced in-house.

(ii) Assurance of *timely availability* because the firm does not have to depend on outside suppliers.

(iii) Availability of the *required facilities* and *capacities* in-house.

(iv) Better control of quality on in-house operations.

(v) Need to preserve *trade secrets* and *design secrets.*

(vi) Savings on *transportation costs* of items from vendor's premises to the buying firm.

When to buy? Some of the reasons that guide managers to make a decision to buy an item from outside sources of supply are:

(i) When the purchase price per unit of the item (including transportation cost) is lesser than the per unit product cost if made in-house.

(ii) When the firm's requirement of an item is low and does not justify investment on special purpose equipments, machines and tools for manufacturing the item in-house.

(iii) Ability of the outside supplier to supply the item at lower cost, higher quality and faster delivery times than would be possible if manufactured in-house.

(iv) When the outside suppliers hold a patent on the needed item.

(v) When opportunity cost of producing is much higher than that of buying.

(vi) When there is no problem of trade secrets or design secrets for the buying firm.

(vii) When there is not enough capacity to make an item and increasing the capacity is not cost effective.

(viii) When the item does not have a long-term requirement.

MAKE OR BUY ANALYSIS

The philosophy underlying the make-or-buy decision is: *"It would be very unusual that one organisation were superior to competition in all aspects of manufacturing or services."* By buying outside, the management of the purchasing firm can concentrate its efforts better on its *main mission* or ***core competency***. This approach can result in substantial *downsizing* and an expanded scope for purchasing in the process. With the world as a market place, the purchasing department is responsible to search for or to develop world-class suppliers suitable for the strategic needs of the firm.

On the other hand, not all raw materials, components and parts required to make a product need to be purchased. Production departments can often make many items in-house at lower cost, of higher quality and with faster deliveries than would be possible in buying from the suppliers. Alternatively, because suppliers may specialise in certain types of production, some parts can be bought from them at lower cost, higher quality, and faster delivery times than would be possible if the firm made them in-house. Hence production department and purchasing department together, routinely perform make-or-buy analyses for the raw materials, parts and components that go into existing products.

SOLVED PROBLEMS

1. *Machines A and B are both capable of manufacturing a product. They compare as follows:*

	Machine A	Machine B
Investment	Rs. 50,000	Rs. 80,000
Interest on capital invested	15% per annum	15% per annum
Hourly charges (wages + power)	Rs. 10	Rs. 8
No. of pieces produced per hour	5	8
Annual operating hours	2000	2000

(i) Which machine will have the lower cost per unit of output, if run for the whole year?

(ii) If only 4000 pieces are to be produced in a year, which machine would have the lower cost per piece?

(iii) Will your answer to (i) above query if you are informed that 12.5% of the output of machine B gets rejected at the inspection stage. If so, what would be the new solution?

Solution :

(i)

Data	Machine A	Machine B
Annual interest charges	Rs. 50,000 × $\frac{15}{100}$ = Rs. 7,500	Rs. 80,000 × $\frac{15}{100}$ = Rs. 12,000
Annual operating charges	Rs. 10 × 2,000 = Rs. 20,000	Rs. 8 × 2,000 = Rs. 16,000
Total annual charges	7,500 + 20,000 = Rs. 27,500	12,000 + 16,000 = Rs. 28,000
Annual production (units) for 2000 hours	5 × 2000 = 10,000 nos.	8 × 2000 16,000 nos.
Cost per unit	$= \frac{27,500}{10,000}$ = Rs. 2.75	$\frac{28,000}{16,000}$ = Rs. 1.75

Machine 'B' gives the lower cost per unit if run for the whole year (for 2000 hours).

(ii)

Data	Machine A	Machine B
Operating hours required for producing 4000 nos	4000/5 = 800 hrs	4000/8 = 500 hrs
Operating charges	Rs. 10 × 800 = Rs. 8,000	Rs. 8 × 500 = Rs. 4,000
Interest charges	Rs. 7,500	Rs. 12,000
Total annual charges	8000 + 7500 = Rs. 15,500	4000 + 12000 Rs. 16,000
Cost per unit	$\frac{\text{Rs.}15,500}{4000}$ = Rs. 3.875	$\frac{\text{Rs.}16,000}{4000}$ = Rs. 4

Machine 'A' gives lower cost per unit.

(iii) If 12.5% of output of Machine B is rejected, net annual production

$$\text{from Machine B} = 16,000 \times \frac{(100 - 12.5)}{100}$$

$$= \frac{16,000 \times 87.5}{100} = 14,000 \text{ nos.}$$

$$\text{Cost per unit} = \frac{28,000}{14,000} = \text{Rs. } 2$$

Even though, unit cost of production on Machine B increases from Rs. 1.75 to 2.0, still machine B continues to be cheaper, if used for 2000 hours in the year.

2. *Methods P and Q are both capable of manufacturing a product. They compare as follows:*

Data	Method P	Method Q
Fixture – cost	Rs. 24,000	Rs. 16,000
– life	6 months	4 months
Tooling – cost	Rs. 2,560	Rs. 4,800
– life	300 pieces	500 pieces
Processing time per piece	6 mts.	4 mts.

The annual requirement is 1500 nos. Operating cost per hour of the process is Rs. 128 for both processes. Material cost is same in each case.

Which method would you choose for production during a period of one year?

Solution :

Data	**Method P**	**Method Q**
Cost of manufacture per year :		
Fixture cost	Rs. 24,000 × 2 = Rs. 48,000	Rs. 16,000 × 3 = Rs. 48,000

(2 nos of fixtures are required per year in method P and 3 nos required in method Q)

Tooling cost	$2,560 \times \frac{1500}{300}$ = 2560 × 5 = Rs. 12,800	$4,800 \times \frac{1500}{500}$ = 4800 × 3 = Rs. 14,400
Operating hours to produce 1500 nos.	1500 × 6/60 = 150 hrs	1500 × 4/60 = 100 hrs
Operating cost per year	Rs. 128 × 150 = Rs. 19,200	Rs. 128 × 100 = Rs. 12,800
Total manufacturing cost per year	Rs. 48,000 + Rs. 12,800 Rs. 19,200	Rs. 48,000 Rs. 14,400 Rs. 12,800
	Rs. 80,000	Rs. 75,200

Since method Q is cheaper than method P, method 'Q' is the choice for production during the whole one year period.

3. *Calculate the break-even point for the following:*

Production Manager of a unit wants to know from what quantity he can use automatic machine as against semi-automatic machine.

Data	Automatic	Semi-automatic
Time for the job	2 mts	5 mts
Set up time	2 hrs	1.5 hrs
Cost per hour	Rs. 20	Rs. 12

Solution :

Let x be the break-even quantity between automatic and semi-automatic machines. This means, for a volume of output 'x', the total cost of manufacture is the same on both automatic and semi-automatic machines.

For quantity = x units

$$\left.\begin{array}{r}\text{Total manufacturing cost on}\\ \text{automatic machines}\end{array}\right\} = \left(2.0 + \frac{2x}{60}\right) \times 20 \text{ Rs.}$$

$$\left.\begin{array}{r}\text{Total manufacturing cost on}\\ \text{semi-automatic machines}\end{array}\right\} = \left(1.5 + \frac{5x}{60}\right) \times 12 \text{ Rs.}$$

If 'x' is the break-even quantity, then

$$\left(2 + \frac{2x}{60}\right) \times 20 = \left(1.5 + \frac{5x}{60}\right) \times 12$$

$$40 + \frac{2x}{60} \times 20 = 18 + \frac{5x}{60} \times 12$$

$$40 + \frac{2x}{3} = 18 + x$$

$$x - \frac{2x}{3} = 40 - 18$$

$$\frac{x}{3} = 22$$

$$x = 66 \text{ units}$$

Hence for quantity upto 65, a semi-automatic machine will be cheaper. For quantity 66, both semi-automatic and automatic machines are equally costly. For quantity more than 66, automatic machine becomes cheaper than semi-automatic machine.

4. *Two alternative set-ups, A and B are available for the manufacture of a component on a particular machine, where the operating cost per hour is Rs. 20.*

	Set-up A	Set-up B
Components/set-up	4000 pieces	3000 pieces
Set-up cost	Rs. 300	Rs. 1500
Production rate/hour	10 pieces	15 pieces

Which of these set-ups should be used for long range and economic production?

Solution :

Considering one set-up

	Set-up A	Set-up B
Set-up cost per year	Rs. 300	Rs. 1500
Operating hours/set-up	$\frac{4000}{10}$ = 400 hours	$\frac{3000}{15}$ = 200 hours
Operating cost	400 × 10 = Rs. 8000	200 × 20 = Rs. 4000
Total manufacturing cost	300 + 8000	1500 + 4000
	= Rs. 8300	= Rs. 5500

Manufacturing cost/piece	$= \frac{8300}{4000} = \text{Rs. } 2.057$	$\frac{5500}{3000} = \text{Rs. } 1.833$

Assuming that the machine is used for production for one year having 2000 hours of working.

For annual production,

	Setup A	Setup B
No. of set-ups	$\frac{2000}{400} = 5$	$\frac{2000}{200} = 10$
Set-up cost per year	5 × 300 = Rs. 1,500	10 × 1,500 = Rs. 15,000
Operating cost	2000 × Rs. 20 = Rs. 40,000	2000 × Rs. 20 = Rs. 40,000
No. of units produced/year	2000 × 10 = 20,000 nos.	2000 × 15 30,000 nos.
Total annual manufacturing cost	1500 + 40,000 = Rs. 41,500	15,000 + 40,000 Rs. 55,000
Manufacturing cost/unit	$= \frac{41,500}{20,000} = \text{Rs. } 2.075$	$= \frac{55,000}{30,000} = \text{Rs. } 1.833$

Since the manufacturing cost for set B is less, use setup B for long range and economic production.

5. *XYZ company is trying to determine how best to produce a new product. The new product could be produced in-house using either process A or process B or purchased from a supplier. Cost data is given below:*

Process	Fixed cost	Variable cost/unit
Make (Process A)	Rs. 8000	Rs. 10
Make (Process B)	Rs. 20,000	Rs. 4
Purchase	Nil	Rs. 20

For what levels of demand should each alternative (i.e., make with process A, make with process B or purchase from supplier) be chosen?

Solution : Let Q_1 be the break-even quantity between process A and process B.

Then

$$TC_A = TC_B$$
$$FC_A + (VC_A \times Q_1) = FC_B + (VC_B \times Q_1)$$
$$8000 + 10Q_1 = 20,000 + 4Q_1$$
$$10Q_1 - 4Q_1 = 20,000 - 8000$$
$$6Q_1 = 12,000$$
$$Q_1 = 2000$$

Purchase cost to purchase 2000 units = 2000 × 20 = Rs. 40,000.

Manufacturing cost to produce 2000 units :

Using process A : Total cost $= 8000 + 10 \times 2000$

$= \text{Rs. } 28{,}000$

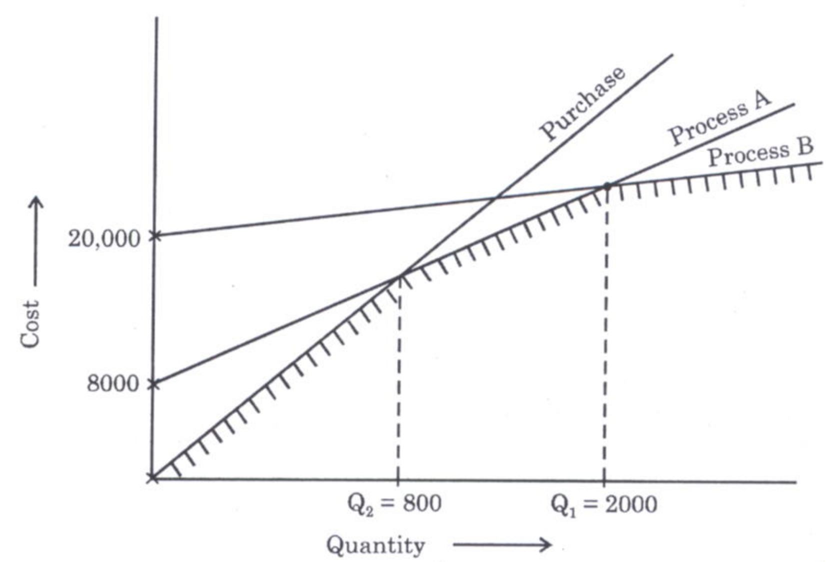
Using process B : Total cost $= 20{,}000 + 4 \times 2000$

$= \text{Rs. } 28{,}000$

Let Q_2 be the break-even quantity between process A and purchasing from outside supplier.

Then

$$FC_A + (VC_A + Q_2) = Q_2 \times 20$$
$$8{,}000 + (10\, Q_2) = 20\, Q_2$$
$$20\, Q_2 - 10\, Q_2 = 8{,}000$$
$$10\, Q_2 = 8{,}000$$
$$Q_2 = 800$$



Conclusion : Upto quantity 800 units, it is most economical to purchase the product. From 800 units to 2000 units, it is economical to make the product using process A. Beyond 2000 units, it is economical to make using process B.

QUESTIONS

1. Define the terms product design, process design and production design.
2. Distinguish between functional design and form design.
3. State the importance of product design.
4. State the functions of product design.
5. State the reasons for product design or redesign.
6. What are the objectives of product design?
7. Discuss the factors influencing product design.
8. Describe the characteristics of good product design.
9. Explain briefly the various approaches to product design.

10. What is computer aided design?
11. Discuss the role of value engineering in product design.
12. What is modular design?
13. What is a process? What are its various types?
14. Define the term "process planning".
15. Distinguish between process design and operations design.
16. What is meant by "process selection"?
17. What is meant by "process strategy"? Discuss the key aspects of process strategy.
18. What is "process management"?
19. Discuss the major process decisions that need to be considered by production/operations managers.
20. What is "make-or-buy analysis"? Discuss the various factors to be considered in make-or-buy decisions.

I PROBLEMS

1. Machines K and L are both capable of manufacturing a product. They compare as follows :

Data	M/CK	M/CL
Capital investment	Rs. 60,000	Rs. 1,00,000
Interest on capital	15%	15%
Operating cost/hour	Rs. 12	Rs. 10
Production output/hour	6 pieces	10 pieces

Factory overhead cost = Rs. 1,20,000.

Working hours per year (on 2 shifts/day basis) = 4000 hours.

(a) Which machine would you choose for regular production throughout the year?

(b) If only 4000 pieces are to be produced in one year which machine would you choose?

(c) For how many pieces of production per year the cost of production would be the same on either machine?

2. A factory can manufacture two products A and B by using either of two processes P or Q. Product 'A' is expected to sell at Rs. 70 per unit and product 'B' at Rs. 30 per unit. The operating data are as follows :

Data	With Process P	With Process Q
Output of Product A	200 units/day	400 units/day
Output of Product B	300 units/day	200 units/day
Quantity of raw material usage	1000 kg	1000 kg
Labour usage	300 man-hours	250 man-hours
Electric energy consumption	1000 kw hr	1500 kw hr
Cost of raw material per kg	Rs. 20	Rs. 30
Labour cost per man hour	Rs. 5	Rs. 5
Electric energy cost per kwhr	Rs. 1.50	Rs. 1.50

(i) Compare total productivity of both of the alternatives and decide on the choice of process P or Q.

(ii) If out of the three inputs, labour becomes a critical input, what would be your preferences; process P or Q?

3. The annual requirement of a component is 3000 nos. X and Y are two methods of manufacturing the component using different fixtures and tooling on the same machine. Operating cost of the machine is Rs. 150 per hour. Material cost is same in each case.

Data		Method X	Method Y
Fixture	- cost	Rs. 34,000	Rs. 26,000
	- life	4 months	3 months
Tooling	- cost	Rs. 3,500	Rs. 5,000
	- life	300 pieces	500 pieces
Processing time per piece		5 mins.	3 mins.

Which method would you choose for production during a period of one year?

4. XYZ co. manufactures an electronic product. A new model developed, requires a new design of a sub-unit for this product. XYZ co. is considering three alternatives *viz.*, *(a)* whether it should buy the sub unit from a vendor, *(b)* produce the sub unit using manual assembly system or *(c)* produce the sub unit using an automated assembly system based on the data given below:

Data	Decision		
	Buy	Produce using manual assembly	Produce using automated assembly
Annual requirement (units)	1,00,000	1,00,000	1,00,000
Fixed cost per year	–	Rs. 2,50,000	Rs. 5,00,000
Variable cost per unit	Rs. 10	Rs. 7.5	Rs. 6

(i) What should XYZ company decide? Buy, produce using manual assembly or produce using automated assembly?

(ii) At what volume would XYZ company be indifferent between manual and automated assembly?

(iii) At what volume would XYZ co. switch over from buying to producing, using manual assembly?

(iv) What other considerations would be important in this decision?

5. A company having a job shop machining facility, manufactures, parts for automobile manufacturers. The company wants to improve its competitiveness. Three alternatives being considered are *(a)* cellular manufacturing, *(b)* CNC machines, *(c)* Flexible manufacturing system (FMS). The costs of these alternatives are given below:

	CM	CNC	FMS
Annual production (units)	1,00,000	1,00,000	1,00,000
Annual fixed costs	Rs. 90,000	Rs. 1,90,000	Rs. 3,20,000
Variable cost per unit	Rs. 29.40	Rs. 28.50	Rs. 27.30

(i) On the basis of economic analysis, rank the three alternatives *viz.*, CM, CNC and FMS.

(ii) If 1,50,000 units are to be produced in an year, what would be the most desirable and least desirable alternatives?