

PROCESS PLANNING

PROCESS PLANNING : Instructional Objectives

After studying this unit, the student should be able to :

- (i) Explain how a product is designed.
- (ii) Explain the steps involved in process design.
- (iii) Enumerate the factors affecting process design.
- (iv) List the types of production and their characteristics.
- (v) Distinguish between specialization, simplification and standardization.
- (vi) Define process planning and list the steps involved in process planning.
- (vii) State what is BOM (Bill of Materials) and its uses.
- (viii) State the data that will be present in a process sheet, and the uses of process sheet.
- (ix) Explain "Routing" and "Route Sheet" in the context of process planning.
- (x) Calculate man-hrs. and machine-hrs. for a manufacturing situation.
- (xi) Explain the use of computers in process planning and cost estimation.
- (xii) State the two approaches adopted in CAPP (Computer Aided Process Planning).
- (xiii) Explain what is Retrieval CAPP system and Generative CAPP system.
- (xiv) Distinguish between Retrieval CAPP system and Generative CAPP system.
- (xv) State the advantages of CAPP.
- (xvi) State the factors involving in selecting a particular process.
- (xvii) List the factors involved in machine selection.
- (xviii) List the process selection parameters.
- (xix) State the parameters involved in material selection.
- (xx) List the documents required for process planning.
- (xxi) Develop manufacturing logic involved in process planning by studying certain examples.
- (xxii) Select cost optimal process using break-even chart.
- (xxiii) Draw a break-even chart given various cost elements.
- (xiv) Work out certain problems involving break-even quantity.
- (xv) Determine break-even quantity from various cost data given.

PRODUCT DESIGN

A product is designed to meet certain functional requirements, and to satisfy the customers needs. At the same time product must be aesthetically appealing to the customer or user. New technology and new materials currently available will also be explored during the product design stage. A product

consists of assemblies, sub-assemblies and component parts. If the product is to be manufactured to customer's specifications, the design is provided by the customer. The manufacturer's product design department will not be involved.

If the product is proprietary, the manufacturing firm is responsible for the design and development of the product. The cycle of events that initiates a new product design often originates from the sales and marketing department. The departments of the firm that are organized to perform the product design function might include, Research and Development, Design engineering, Drafting, and perhaps a Prototype shop.

The product design is documented by means of *component drawings, specifications, and a bill of materials that defines how many of each component go into the product*. A prototype is often built for testing and demonstration purposes. The manufacturing engineering department is sometimes consulted for advice on matters of produceability or manufacturability. Questions like "What changes in design could be made to reduce production costs without sacrificing function" ? are raised and answers sought. Cost estimates are prepared to establish an anticipated price for the product.

Upon completion of the design and fabrication of the prototype, the top company management officials are invited for a presentation and discussion held. The design engineer gives a presentation and demonstration of the product so that management can decide whether to manufacture the item. The decision is often a two-step process. The first is a decision by engineering management that the design is approved. The second step is a decision by top corporate management as to the general suitability of the product. This second decision represents an authorization to produce the item.

MANUFACTURING PLANNING

The information and documentation that constitute the design of the product are considered in the *manufacturing planning*. The Departments in the organization that perform manufacturing planning include manufacturing engineering, industrial engineering, and production planning and process planning.

PROCESS DESIGN

Industry employs a set of procedures in the design of manufacturing processes. Generally speaking this activity starts with the receipt of the product specifications and ends with the final plans for the manufacture of the product. In a broad sense this pattern of activity is uniform, regardless of the kind of product or the type of manufacturing involved. The steps involved in process design are as follows.

- (i) A careful review of the product design and specifications to make sure that economical manufacture is feasible.
- (ii) Determination of the methods of manufacture that will result in the optimum manufacturing cost.
- (iii) Selection or development and procurement of all machines, tools, and other equipment required for the manufacture of the product at the required quality and rate of production.
- (iv) Layout of the production area and auxiliary spaces, and installation of the manufacturing facilities.
- (v) Planning for and establishing the necessary control of materials, machines, and manpower to ensure the effective utilization of the manufacturing facility for the economical production of the product.

The above steps may be identified as functions of various activities, such as manufacturing engineering, process engineering, process planning methods engineering, or tool engineering. The scope of process-design activity can be identified as all work that is necessary to arrange for the manufacture of the product by the most economical means.

BASIC FACTORS AFFECTING PROCESS DESIGN

There are three basic factors that affect the design of a manufacturing process, namely:

- (i) The volume or quantity of the product to be manufactured.
- (ii) The required quality of the product.
- (iii) The equipment that is available, or that can be procured, for the manufacture of the product.

The volume to be manufactured must always be considered as the volume to be produced within a given period — or as the rate of production. In this manner it can be related to the capacity of the manufacturing equipment under consideration and the best methods selected accordingly.

The anticipated volume should be based also upon a sales forecast. This is of particular importance in the introduction of a new product. Funds should be allocated for the improvement of processes only when the forecast indicates such a volume of sales that an appropriate return on the investment can be realized.

Generally speaking, the greater the volume of the product to be produced, the greater is the opportunity to incorporate advanced methods of manufacture into the design of the manufacturing process.

The number of identical units to be produced vitally affects the selection of manufacturing methods. The savings per unit of product or per component part, when multiplied by the total volume to be produced will give an idea of the money that can be allocated for the purchase of modern equipment. It may justify new and better machine tools, the use of numerically controlled machines, etc. It will also justify better auxiliary equipment such as jigs, fixtures, or dies, which will in turn increase the productive capacity of the existing equipment in the plant.

Methods of manufacture vary widely with the volume to be produced. The production of heavy industrial equipment and machinery involves very few units of product, requires skilled machinists or other craftsmen using general-purpose machines and tools, and assembly is by skilled labour. On the other hand, the mass production of washing machines, refrigerators, TVs, automobiles, and similar goods is accomplished with a large proportion of automatic machinery and on a planned assembly line that requires a minimum of skill.

TYPES OF PRODUCTION

Depending upon the type of industry and manufacturing situations, production can be divided into various types as follows:

- (i) *From selling point of view*, products are manufactured either to customers' order or to stock. In manufacturing to customers' order, production of any product is taken up only when you have customers' orders on hand. In manufacturing to stock, the items are produced and stored and customers' requirements are met from the stock of the finished goods.

(ii) *From method of production point of view*, it can be divided into following two types:

- (a) Intermittent production, and
- (b) Continuous production.

These two types differ in the length of time the equipment set-ups is used without change. If a machine set-up is used for a very short period and then changed to make another product, it is called intermittent production. If a machine set-up is used for months without change it is called continuous production. It may be noted that difference in two types of production has nothing to do with regularity of industry's operation. Comparison of intermittent and continuous types of production is shown in a Tabular form. Table 2.1.

JOB, BATCH AND MASS PRODUCTION

1. Job Production

In this type of production the products are manufactured directly to customer's orders and the quantity produced is also small, in many cases it may be one piece only. The work is started only when the organization has orders on hand. The main characteristics of this type of production are:

- (i) Each job is different from the previous one as regards specifications, quality and quantity.

Table 2.1. Comparison of Intermittent and Continuous Type of Production

<i>Sr. No.</i>	<i>Criteria for comparison</i>	<i>Intermittent production (job production or batch production)</i>	<i>Continuous production (mass production)</i>
1.	Quantity or volume produced	Small quantity	Large quantity
2.	Variety of product	Large variety	Small variety
3.	Machines used	General Purpose Machines (GPM)	Special Purpose Machines (SPM)
4.	Plant layout	Process controlled	Product controlled
5.	Machine capacities	Unbalanced	Balanced
6.	Raw material inventories	High	Low
7.	Inprocess inventories	High	Low
8.	Material flow	Intermittent	Continuous
9.	Material handling	Manual or trucks	Conveyors
10.	Operator's skill	Highly skilled	Unskilled or semi-skilled
11.	Job instructions	Detailed job instructions required	Less job instructions required
12.	Flexibility to product change	Flexible	Difficult and involves spending of lot of money
13.	Work stoppages	Less frequent	More frequent
14.	Output rate	Can be changed	Difficult to change

- (ii) Flow of material is not continuous *i.e.*, it is intermittent.
- (iii) General purpose machinery is used, hence less initial investment in equipment.
- (iv) Similar type of machines are grouped together.
- (v) Highly skilled operators are needed.
- (vi) Each work has to be planned and scheduled separately.
- (vii) Raw material inventories are high.
- (viii) Prior planning is not possible.

From the above characteristics it is clear that job order production is a case of intermittent production. The examples of job order production are manufacture of aircrafts large turbo-generators, ships, chemical plants, gates, doors and windows of houses etc.

2. Batch Production

In this type, the products are made in small batches and in large variety. The orders may be repeated with intervals of time. The characteristics of this type of production are:

- (i) Products are manufactured in batches.
- (ii) General purpose machines are used.
- (iii) Flow of material is intermittent.
- (iv) Plant layout is process type.
- (v) In process inventory is high.
- (vi) Process and product planning is done for each batch.
- (vii) Work loads on various machines or sections are unbalanced.
- (viii) Machine operators are highly skilled.

Batch production is also a form of intermittent production. This is a very common type of production. Drugs, chemicals, paints, sheet metal components, forgings and parts manufactured on turret/capstan lathes come under this type.

3. Mass Production

Mass production means the production of items in large quantity using very specialised machines and processes. Items like metal screws, nuts and bolts and plastic products are made in mass production. In this type of production there is a continuous and steady flow of materials. The various characteristics of mass production are:

- (i) Small varieties and large volumes are manufactured.
- (ii) Product type plant layout is used.
- (iii) The flow of work is balanced *i.e.*, machine capacities are balanced.
- (iv) Specialised machines and processes are used, hence high initial investment in equipment.
- (v) Materials move by conveyors.
- (vi) It results in lowest cost of production.
- (vii) Easier production planning and control.
- (viii) Inventory of work in progress is small.

Various characteristics of different types of production are given below:

There are four types of production:

- (a) Job shop production.
- (b) Batch production.

- (c) Mass production of discrete products or components, and
- (d) Production using Continuous—flow processes.

The characteristics and description of the four types of production are given in Table 2.2. The relationships among the four types in terms of product variety and production quantities can be conceptualized as shown in Fig. 2.1. There might be some overlapping of the categories as the figure indicates.

Table 2.2: Four Types of Production

S. No.	Type of production	Characteristics, Description & Examples
1.	Job shop production	Production of low quantities, often one of a kind of specialized products. The products are often customized and technologically complex. CNC machines are widely used in job shop production. (Examples: Prototypes, Aircraft and Machine tools)
2.	Batch production	Production of medium lot sizes of the same product or component. The lots may be produced at periodical intervals. CNC machines and Robots are widely used in batch production of industrial products and machinery. (Examples : Production of books in printing presses and cloth in textile mills).
3.	Mass production of discrete products	Dedicated production of large quantities of one product (with perhaps limited model variations). Mass production of discrete components involve the use of transfer machines, automated assembly lines, and automated materials handling systems, robots and extensive use of computers for monitoring the production. (Examples: Automobiles, Engine blocks and Home appliances)
4.	Production using Continuous-flow processes	Continuous dedicated production of large amounts of bulk product. (Examples: Production of chemicals and petroleum products in Continuous chemical plants, and Oil refineries)

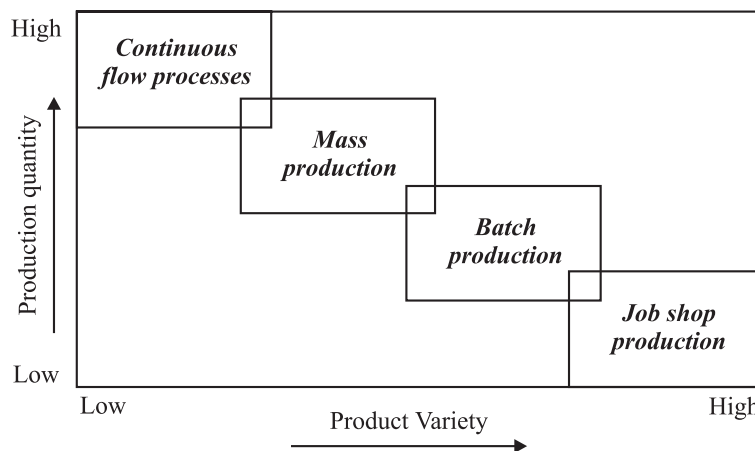


Fig. 2.1. Four types of production in relation to production quantity and product variety

SPECIALIZATION, SIMPLIFICATION AND STANDARDIZATION

Modern manufacturing has a number of characteristics that make for increasing success year after year. Some of the characteristics are Specialization, Simplification and Standardization.

1. Specialization : One of the important characteristics of manufacturing today is that of specialization. Some manufacturers concentrate on producing a single item, and others restrict production to a line of related products. The result of such specialization is usually lowered cost of production and improved quality.

Specialization also means the division of work or effort, and this occurs at the operator (worker) level and at the management level.

At the worker level there are those who work on jobs requiring a great skill, such as machinists, tool and die makers and welders, such craftsmen become high skilled specialists. Other workers do semi-skilled jobs. Both skilled and unskilled operators keep our mass-production and assembly lines running day after day. Although such specialization has elements of monotony and inflexibility, it results in high volume production at low cost.

Specialization of effort also operates at the management level. Management effort, generally, is divided into various special functions such as design, engineering, sales and finance and so on as the business grows in size and complexity. Within any one specialization there will be further specialization or sub-specialization. Engineering, for example will have its specialists in mechanical electrical and automobile work.

The efficiency of the engineer will probably increase as the scope of his assigned responsibility is narrowed.

Specialization as applied to different activities on the shop floor lead to the division of labour. This means that instead of one operator completing a whole product, he completes one small operation on the product hence becoming a specialist at that one activity. This principle is used in modern mass production and assembly lines.

Considering this machines are also designed for special purposes (SPM: Special Purpose Machines as opposed to GPM: General Purpose Machines) which will complete one specific operation as efficiently as possible on one type of component. This ensures a high degree of uniformity of work turned out. *i.e.*, consistency in the quality of work.

Companies/Industries concentrate their productive effort upon a limited number of products depending on their core competencies and manufacturing facilities available. Because of such specialization they will become more experts and specialists at producing a certain range of products and enjoy all the economic advantages which come as a result of such efforts.

2. Simplification : The concepts of specialization, standardization and simplification (known as three S's) are closely inter-related and lead to inter-changeability in manufacturing.

Simplification is the process of reducing the variety of products manufactured (also known as variety reduction).

3. Standardization : It is the broader concept of simplification and can be defined as the establishing of desirable criteria with respect to size, shape, material, quality etc. of product and if practical will lead to simplification of a company's products. This will inturn make mass production economically viable if the demand for the standardized product is sustained.

A product involves assemblies, sub-assemblies and component parts. If more than one product is manufactured in the industry, there is usually standardization of sub-assemblies or component parts among the different products.

Standardization : Results in overall cost reduction and economy in purchasing and manufacturing.

In this respect designs plays an important role in ensuring that there is standardization amongst all the assemblies and sub-assemblies and various components of the products manufactured.

Standardization promotes interchangeability : Interchangeability, or interchangeable manufacture, means that any standardized part produced can be interchanged such that any component will assemble equally well with any mating part without any fitting being necessary. The parts produced must be as near identical as possible, and standardization of all dimensions, tolerances fits and other part features ensure this.

Standardization : This is a process which leads to the establishment of desirable criteria with respect to material, size and other quality characteristics, to which every one can adhere. If they do, then they would expect that the standard would meet all their requirements and enable them to manufacture and stock the minimum variety of parts.

The greatest economic benefit can be obtained if every design makes use of standard parts, such as screws, nuts, fasteners, splines, shafts, bushes, gears etc. manufactured using standard materials, standard cutting tools, inspected using standard gauges, stored and despatched in standard containers.

Greatest economy can be effected if standard parts (screws, bushings, handles, clamps) can be incorporated into a new product. Standard parts, since they are made in large numbers, can be manufactured at a lower cost, than special jobs. Also, standard parts can be salvaged from old sub-assemblies and used again.

Every time the engineer calls for a special item (non-standard type), The work of preparation of specification becomes difficult and costs of processing such item also rise.

Standards are available to the engineer covering a wide variety of features such as

- (i) Dimensions, tolerances, and fits,
- (ii) Material specifications and properties; raw material sizes,
- (iii) Machines, tools, gauges, instruments,
- (iv) Methods of assessing and inspecting parts, sub-assemblies, assemblies and products; and
- (v) Installation and commissioning of equipment and machinery,

Hand books and standard Data sheets contain the specifications and standards for the above. The application of standards enhances quality.

PROCESS PLANNING

When the design engineers have designed the product, the assembly drawings and working drawings of individual components are made. The process planners have to see how the product can best be made to meet the specifications mentioned in the part drawing.

Process plan : The detailed instructions for making a part or a component. It includes such information as the operations, their sequence, machines, tools, speeds and feeds, dimensions, tolerances, stock removed, inspection procedures and time standards (*i.e.*, cycle time).

Process planning : It may be defined as the determination of the processes and the sequence of operations required to make the product. It consists of devising, selecting and specifying processes, machine tools and other equipment to transform the raw material into finished product as per the specifications called for by the drawings.

The purpose of process planning is to determine and describe the best process for each job so that:

- (i) Specific requirements are established for which machines, tools and other equipment can be designed or purchased.
- (ii) The efforts of all engaged in manufacturing are co-ordinated.
- (iii) A plan is made to show the best way to use the existing or proposed facilities.

STEPS INVOLVED (PROCEDURE) IN PROCESS PLANNING

The following are the steps involved in carrying out the process planning manually. Past experience of process planners are used in arriving at the economical manufacturing of the product.

The steps involved in process planning are :

- (i) The finished product is analyzed so that its sub-assemblies and individual components are identified from manufacturing point of view.
- (ii) Prepare a Bill Of Materials [BOM] for all components of the product which forms a basis for purchase of raw materials.
- (iii) Decide which parts are to be manufactured in the plant and which parts are to be purchased from the market depending upon the facilities available in the plant, *i.e.*, decision with regard to “make” or “buy” to be taken.
- (iv) Choose the appropriate blank size *i.e.*, raw material size and select the most economical process to be followed to manufacture components of the product. This is done by comparing the various possible methods of obtaining the final product. The basic factors of volume to be produced, *i.e.*, production quantity, required quality of the product and the capabilities of the equipment available are carefully considered in this step.
- (v) Decide the sequence of operations to be performed on each component in the process selected.
- (vi) Each operation is assigned to the type and size of machine or work station that will perform the job most economically.
- (vii) Depending upon the accuracies called for by the drawings, determine the machine tools to do the operations
- (viii) Determine the need for any special equipment like jigs, fixtures, cutting tools etc.,
- (ix) Determine the inspection stages and instruments required and the need for designing any inspection devices (say gauges, etc.).
- (x) Estimate the standard time for performing the job.
- (xi) Determine the type of labour (skilled, semi-skilled or unskilled) required to do the job.

Process planning has been traditionally carried out by methods engineers, manufacturing engineers, industrial engineers or by process planners.

BILL OF MATERIALS (BOM)

Bill of materials is a tabular statement specifying all the components required for completing an assembly or sub-assembly. The items listed in a bill of materials are :

- (i) Name of individual part, and No. required to complete an assembly and material of the part.

- (ii) Whether the individual parts are to be manufactured from within or whether it is to be bought out. If the part is a standard item (*e.g.* bolts, nuts, bearings, washers, rubber/plastic moulded parts) it can be bought out economically than making it in the shop.
- (iii) Name of engineer preparing the BOM, date of preparation and his signature. Bill of materials enables planning for items to be manufactured in house, raw material required and planning for procurement of bought out items and for making cost estimates. BOM is also known as parts list and is generally incorporated in the drawing of assembly or sub-assembly.

Uses of Bill Of Materials (BOM) :

Production Planning and Control Department uses BOM for deciding manufacturing and scheduling dates.

Process planners/Process engineers use it to know for what parts process planning is to be carried out.

Process planners and methods engineers (industrial engineering dept.) uses BOM in estimating standard time and time allowances (cycle time) for manufacturing and assembly operations.

Purchase and Stores Department compiles several BOM's and orders purchasing of all standard items so that these parts are made available at the time of assembly.

PROCESS PLANNING SHEET

The whole information determined by the process planning is recorded in a tabular form in a sheet called process planning sheet. This document is provided to the shop personnel for their use. The character of this sheet will vary for different organisations depending upon the production conditions and degree of details required.

In general the following data is listed for each component of the product in the process sheet.

- (i) Information regarding the main product, of which the component being manufactured is a part *i.e.*, name and part number of the main product.
- (ii) Name, part number, drawing number of the component and number of *i.e.*, no. of components required per product.
- (iii) Information concerning the blank *i.e.*, raw material used, size and weight of stock.
- (iv) Operations are listed in proper sequence along with the shops in which these operations will be performed.
- (v) Information regarding machines used for each operation.
- (vi) Data on jigs, fixtures and other special tools required.
- (vii) Inspection devices needed for inspection.
- (viii) Cutting data *i.e.*, speeds, feeds & depth of cut for each machining operation.
- (ix) Elements of standard time such as set-up time, handling time and machining time for the job.

A typical process sheet is shown in Table 2.3.

The process planning sheet is prepared by the process engineer in consultation with the tool engineer, industrial engineer, or methods engineer.

USES OF PROCESS SHEET

A process sheet is a very important document which forms a basis for all planning, scheduling and despatching functions. Also it helps in advance planning and for purchase of raw materials design and manufacture of special tools, jigs, fixtures and inspection devices. It helps in estimating the cost of the product before it is actually manufactured. It also helps in planning for man power required for doing the job.

Process Planning, Routing and Process Sheet (Route Sheet)

After finalizing all the details of Product Design, manufacturing planning is to be carried out. Process planning is an integral part of manufacturing planning.

Process planning consists of determining the sequence of the individual processing and assembly operations needed to produce the part.

Routing

Routing may be defined as the planning of where and by whom work shall be done, the path or route to be followed by the work and necessary sequence of operations. Taking from raw material to the finished product, routing decides the path and sequence of operations to be performed on a job. Routing starts from the component drawings and aims at optimum utilization of resources. Routing forms the basis for the scheduling and despatching functions of the production control department.

Routing Procedure : The following procedure is generally adopted for routing :

- (i) From the drawings the final product is analysed from manufacturing point of view and broken into sub-assemblies and components.
- (ii) A detailed bill of materials is prepared.
- (iii) Based on the facilities and capacities available, a decision is taken regarding the components which can be manufactured in the plant and which can be bought from outside.
- (iv) For each component to be manufactured in the plant, the operations which must be performed to transform the raw material into final shape are established and listed in proper sequence.
- (v) A list of tooling required of each stage is also prepared. The information obtained in step (iv) and (v) is recorded in a sheet called **Route Sheet**, along with other information like component name, Part No., material, quantity to be produced, etc.,

Route Sheet

The Route Sheet is a listing of the sequence of operations which must be performed on the work part. It is called Route Sheet, because it lists the machines (machine tools) through which the part must be routed in order to accomplish the sequence of operations.

A sample proforma for route sheet is shown in Table 2.4.

The document used to specify the process sequence is called a Route Sheet. Process planning sheet and Route Sheet are one and the same. The term “process planning sheet” is more widely used in industries now a days.

The manufacturing engineering and industrial engineering departments and process planners are responsible for process planning and preparation of Route Sheets.

Table 2.4 : Route Sheet

Component No..... Drawing No.....
 Name of component..... Quantity.....
 Material.....

<i>Operation No.</i>	<i>Deptt./ Section</i>	<i>Operation Description</i>	<i>Machine</i>	<i>Tool required</i>	<i>Cutting data</i>	<i>Jigs/ Fixtures and other accessories</i>

Calculation of Man-Hours and Machine-Hours

A man-hour is defined as the availability of one man (operator) for one hour for doing a job. Availability of man-hours is calculated when the work is done by manual labour as in a scooter assembly shop, welding, making sand moulds and cores in a foundry shop, packing of soaps and detergents, etc. The requirement of man-hours is calculated to estimate the number of men (operators) required to complete the job.

A machine-hour is defined as the availability of one machine for one hour. Availability of machine-hours is calculated in production when work is done mainly with the help of machines as in the case of production with automatic machines, in gear shops manufacturing gears, or using lathe for machining turned components etc.

The requirement of machine hours is calculated to estimate the number of machines required to complete the job.

The number of man-hours or machine-hours available during a particular period is calculated as follows :

- (a) Total number of days in the period under consideration = X
 (b) Number of holidays in the period = A
 (c) Number of shifts per day = B
 (d) Number of hours per shift = C
 Numbers of working hours available = $(X - A) \times B \times C$

This gives the total or gross man-hours or machine-hours available for working. But in actual practice allowances for absenteeism, power failures, repair and maintenance, rest and other factors have to be considered. The actual or net machine-hours or man-hours available is less than the gross man-hours or machine-hours available and it depends on the type of industry and type of labour available.

Example : Calculate the net machine-hours available in a factory from the following data for month of June :

- | | | |
|--|---|----------------|
| (1) Number of milling machines | = | 8 |
| (2) Number of working days | = | 25 |
| (3) Number of shifts per day | = | 2 |
| (4) Time lost due to maintenance and repairs, etc. | = | 3 hrs. per day |
| (5) Number of hours/shift | = | 8 |

Solution : For One Milling Machine :

$$\text{Number of working days in June} = 25$$

$$\text{Net working hours available per day/machine} = (8 \times 2) - 3 = 13 \text{ hrs.}$$

$$\text{Net machine-hours available per machine per month} = 13 \times 25 = 325 \text{ hrs.}$$

$$\text{Net machine-hours available for 8 machines/month} = 325 \times 8 = 2600 \text{ m/c hrs.}$$

Use of Computers in Process Planning and Cost Estimation

There are different levels of involvement of the computer in the operations of any plant or industry.

The computer is used indirectly to support the production function but there is no direct connection between the computer and the process. The computer is used “off-line” to provide information for the effective planning and management of production activities.

Cost Estimating using Computers : The task of estimating the cost of a new product has been simplified in most industries by computerizing several of the key steps required to prepare the estimate. The computer is programmed to apply the appropriate labour and overhead rates to the sequence of planned operations for the components of new products. The programme then sums up the individual component costs from the engineering bill of materials to determine the overall product cost.

Computer Aided Process Planning (CAPP) : Process planning is concerned with the preparation of route sheets which list the sequence of operations and work centres required to produce the product and its components. CAPP systems are available today to prepare these route sheets.

Process planning involves the preparation and documentation of the plans for manufacturing the products. Computer-Aided Process Planning (CAPP) is a means of implementing this planning function by the use of computers

Computer Aided Process Planning represents the link between design and manufacturing in a CAD/CAM system. Process planning is concerned with determining the sequence of processing and assembly steps that must be accomplished to make the product. The processing sequence is documented on a sheet called a route sheet. The route sheet typically lists the production operations, machine tools, work centres or work stations where each operation is performed, jigs, fixtures and tooling required and standard time for each task.

In manufacturing enterprises, there has been an interest in automating the task of process planning by means of CAPP systems. The shop-trained engineers who are familiar with the details of machining and other processes will be retiring, and these experienced engineers will not be available in the future to do the process planning. An alternative way of accomplishing this function is needed and CAPP systems are providing this alternative.

Computer Aided Process Planning (CAPP) Systems are designed with two approaches in mind. These approaches are called :

- (a) Retrieval CAPP Systems, and (b) Generative CAPP Systems,

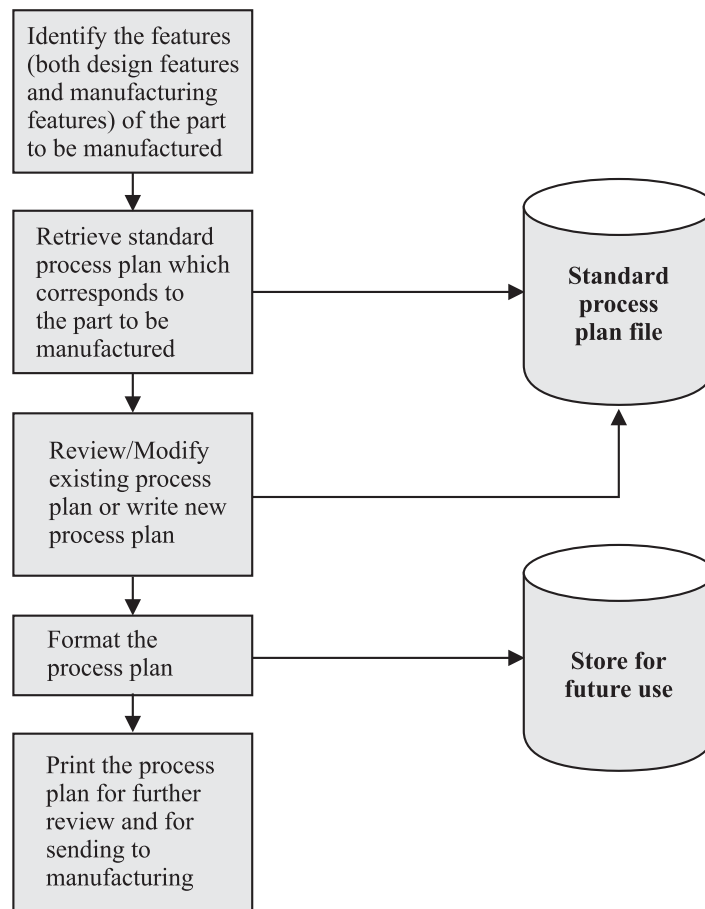
Approaches to process planning : Details given earlier are the basic steps involved in process planning when it is carried out manually by an experienced process planner. CAPP (Computer Aided Process Planning) involves the use of an interactive computer system to automate the works involved in preparing a process plan. There are fundamentally **two different approaches** when computers are used in the process planning task.

- (1) Variant or Retrieval method of process planning.
- (2) Generative method of process planning.

1. Variant or Retrieval Method of Process Planning (Retrieval CAPP System)

In this method, the computer makes a search of its storage or a data base or a no. of standard or completed process plans that have been previously developed by the company's process planners. The development of the data base of these process plans requires substantial knowledge of machining, time and efforts. Using the current design data supplied by the CAD system, (after a component has been designed and dimensioned), it searches for a process plan that was based on a part of similar design. (This search can make effective use of GT, Group Technology, design coding to simplify the search for similar part design).

The process plan **retrieved** is then modified or suitably **varied** (*i.e.*, altered) by the process planner, to suit the exact requirements of the current part design. The use of Computer and Group



Procedure for developing the Retrieval type Computer—Aided Process Planning (CAPP) system

Technology (GT) to search for the most appropriate or similar part design, and to retrieve the process plan for that design, significantly reduces the work required of the process planners. This also saves considerable amount of time required to develop a process plan for a new part. The task of process planner becomes one of modifying the existing plan to suit the particular dimensions of the current part. (*i.e.*, the selected process plan is provided to the user for modification and variation).

Process planners are required to perform the entire process planning method only in the case of a completely new part design.

This approach of process planning is also known as Retrieval CAPP system. This is based on the principles of Group Technology and parts classification and coding. One of the pre-requisites for implementation of this method is that the industries must develop and maintain a large computer data base of standard completed process plans. In addition, the part designs are to be developed using CAD systems.

2. Generative Method of Process Planning (Generative CAPP System)

The second method of computerized process planning is the generative method. In this method the computer uses the stored manufacturing and design data to generate a complete list of all possible process plans that could be used to manufacture the current part. It then exhaustively searches this list for the one which optimizes the cost function. This method always yields the optimum process plan for manufacturing a particular part.

However, it has a very high cost in terms of time and computer processing expenses. The computations required to provide even a single process plan for an arbitrary part design can be enormously complex. To repeat this for every feasible process plan or a part can become very costly.

This approach of process planning is also known as **Generative CAPP System**. Both the approaches viz. Variant (or retrieval) method of process planning and Generative method of process planning involves a systematic development of Code Numbers using Group Technology concepts and principles for the design and manufacture of the part. Both of these methods of computerized process planning can be enhanced through the application of AI (Artificial Intelligence) in the form of expert systems.

Benefits of CAPP

The benefits derived from computer aided process planning are the following

1. **Process rationalization and standardization** : Automated process planning leads to more logical and consistent process plans than when process planning is done completely manually.
2. **CAPP helps in arriving at standard and consistent process plans** : Standard plans tend to result in lower manufacturing costs and higher product quality.
3. **Increased productivity of process planners** : The systematic approach and the availability of standard process plans in the data files permit more work to be accomplished by the process planners.
4. **Reduced lead time for process planning** : Process planners working with the CAPP system can provide route sheets in a shorter lead time compared to manual preparation.
5. **Improved legibility and readability** : Computer prepared route sheets are legible and easier to read than manually prepared route sheets.
6. **Incorporation of other application programmes** : The CAPP programme can be integrated with other application programmes, such as estimation of standard time, cost estimating and formulation of work standards.

Practices of Process Planning

The practices of process planning vary widely in modern industry, depending on such factors as :

- Type of product
- The equipment available, and
- The volume of production (*i.e.*, production quantity)

The individual responsible for carrying out process planning / process analysis is the Process Engineer also known as process planner, process analyst or methods engineer. To be effective on his or her job, the process analyst must be familiar with material characteristics and manufacturing processes. Knowledge of the nature, types, and properties of standard materials and new materials will assist the process analyst in selecting the most appropriate process, equipment and methods for manufacturing a particular product. The process analyst must also be familiar with engineering drawings and product design. Drawings provide the part configuration and the dimensional tolerances and specifications that need to be met by the manufacturing process selected

In addition, the process planner must be familiar with the operating characteristics and costs of the production and tooling equipment, either available in the plant or to be purchased.

Process Planning starts with a careful examination of the drawing or design of the part. The process planner must be able to analyze the engineering drawing and visualize the three dimensional part configuration. The part configuration must then be analyzed to determine its basic geometric components. Identifying these basic geometric elements assists the process planner in selecting the most appropriate process to manufacture the product.

Process Selection

Consideration should be given to the following factors in selecting a particular process

1. Nature of part, including materials, tolerances, desired surface finish and operation required.
2. Method of fabrication including machining or assembling of similar parts or components.
3. Limitation of facilities including the plant and equipment available.
4. Possibility of likely product design changes to facilitate manufacturability or cost reduction.
5. In-plant and outside materials handling systems.
6. Inherent process to produce specified shape, surface, finish to give desired mechanical properties.
7. Available skill level of operators for the production.

Sometimes the following additional factors affect the selection of a particular process.

- (a) Proposed or anticipated production requirements, including volume requirements, production rates and short- term or long- term production runs.
- (b) Total end-product costs.
- (c) Time available for tooling-up.
- (d) Materials receipt, storage, handling and transportation.

Careful consideration of these factors will result in the selection of the most appropriate process for the manufacture of a particular product.

Selection of an appropriate manufacturing process depends on many factors and requires considerable knowledge, skill and competence of the process planner or process analyst.

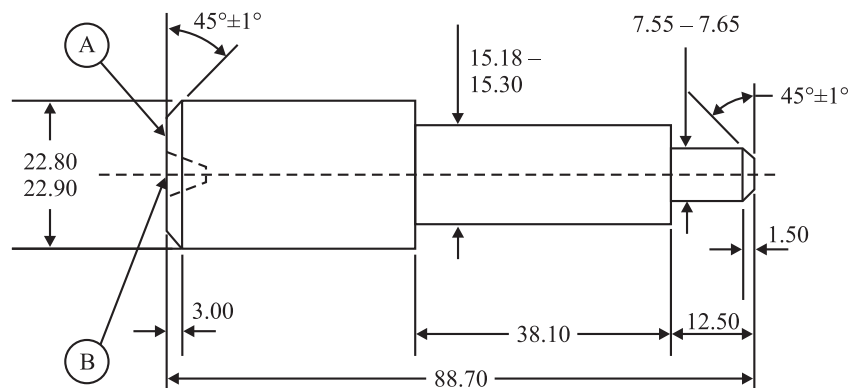
Process Sheet : Once the process (example : machining) has been selected, the next step is to list operations in a logical sequence. The processes are written in a sequential order in the process sheet or operation analysis sheet. The process sheets are used as instruction sheets, for the operator to process the part.

Process sheets format vary widely in industry depending on such factors as type of product, type of industry, type of equipment and type of manufacturing. However, most process sheets include such information as description and numerical order of operations, manufacturing equipment used jigs, fixtures, tools and gauges used, speeds, feeds and depths of cut, material specifications, drawing specifications and revisions, if any.

Process Planning Activities :

Example 1 : A part drawing is shown in Fig. 2.2 (Gear shaft for water pump). The following are the activities/decisions involved in process planning.

1. Study and read the drawing so that the part features are identified. The important feature of the part are:
 - (a) Three concentric cylinders constitute the part.
 - (b) There is one chamfer of $45^\circ \times 3$ mm and one chamfer of $45^\circ \times 1.5$ mm at the ends of the shaft.
 - (c) The dimensional tolerances are ± 0.05 mm and the angular tolerance on the chamfer is $\pm 1^\circ$.
 - (d) Material is SAE 1030 cold drawn steel.
2. Only 5 pieces are required. The most feasible process is machining on a standard centre lathe.
3. The parts can be machined from 25 mm diameter standard stock.
4. One lathe operator is required to complete the order.
5. The next step is to identify the operations. To produce the part the following operations are required:
 - (a) Facing
 - (b) Centre drilling
 - (c) Cutting off (or) part off
 - (d) Turning
 - (e) Chamfering
 - (f) Finishing (removing sharp edges)



Material: 25 mm diameter SAE 1030 cold drawn steel
 All Tolerances : ± 0.05 unless otherwise specified
 All dimensions are in mm. Number of parts required : 5

Fig 2.2. Gear shaft for water pump.

6. In addition, the process planner must estimate the time for each of these operations : the set-up time, the cutting tools needed, jigs, fixtures and gauges required, the machining parameters such as: Cutting speed, feed, d.o.c. (deptt of cut).
7. Completing the process planning sheet. The operations listed are sequenced in numerical order and are listed in the process sheet along with other necessary information. Fig. 2.3

Process Planning Sheet

Oper. No.	Description of Operation	Machine Name or No.	Cutting Tool	Cutting speed		Feed mm/rev	Depth of cut mm	Locating points on drawing	Fixtures, Tools, Gauges, etc.	Remarks
				(m/min)	rpm					
10	Face end	Centre lathe 7071	Facing tool	30	300	Hand	—	A	Use 25 mm lathe chuck	Use 3-jawed universal chuck
20	Center drill end	Centre lathe 7071	Combina-tion center drill	—	650	Hand	—	B		Cutting fluid or oil may be used.
50	Cut off to 88.70 mm length	Centre lathe 7071	Parting cool	30	300	Hand	—	A	Support work with live center to avoid chatter	Use coolant
90										
100	Remove sharp edges	Centre lathe 7071	File or emery cloth		650	Hand	—	—		
<i>No.</i>		<i>Revisions Schedule</i>		<i>Date</i>		<i>Part Identification Details</i>				
1	Added Oper. No. 100		18-1-06	Drawing No. : 76-10 GM,			Stock No. : 48252			
2				Part Name : Gear Shaft			Specification No. : 01-305GM			
3				Material : SAE 1030 CRS			Process Engr.			
4				APPROVED : Date : 16-1-06			Sheet No. 1 of 2 sheets			

Fig 2.3. A typical sample of an operation (process) analysis sheet used in manufacturing.

Machine Selection

Product manufacturing requires tools and machines that can produce economically as well as accurately. Economy depends to a large extent on the proper selection of the machine or process for the job that will give a satisfactory finished product. The selection of the machine is influenced, in turn by the quantity of items to be produced. Usually there is one machine best suited for a certain output.

In small lot or jobbing type manufacture, general purpose machines such as the lathe, drill press, and milling machine may prove to be the best type since they are adoptable, have lower initial cost, require less maintenance, and possess the flexibility to meet changing conditions in the shop.

However, a special purpose machine should be considered when large quantities of a standard product are to be produced. A machine built for one type of work or operation, such as the grinding of a piston or the machining of a cylinder head, will do the job well, quickly and at a low cost requiring only the service of a semi-skilled operator.

Many of the special-purpose machines or tools differ from the usual standard type in that they have built into them some of the skill of the operator. A simple bolt may be produced on either a lathe or an automatic screw machine. The lathe operator must not only know how to make the bolt but must also be sufficiently skilled to operate the lathe. On the automatic machine the sequence of operations and movements of tools are controlled by cams and stops, and each item produced is identical with the previous one. This “transfer of skill” into the machine makes possible the use of less skillfull operators, but it does requires greater skill in supervision and maintenance. Often it is not economical to make a machine completely automatic, as the cost may become prohibitive.

The selection of the best machine or process for a given product requires a knowledge of all possible production methods. Factors that must be considered are:

- (a) Volume of production (Quantity to be produced) *i.e.*, no. of components to be produced.
- (b) Quality of finished product, and
- (c) Advantages and disadvantages of the various types of equipment capable of doing the work.

Too much emphasis cannot be given to the fact that production can be by several methods, but usually there is one way that is most economical.

Factors Influencing Process Selection

After a product design is made process selection is to be carried out. There are several factors which influence the process selection, These are :

1. Shape requirements
2. Size or dimensional requirements
3. Tolerance requirements
4. Surface finish requirements
5. Annual volume requirements (*i.e.*, production quantity required per annum)
6. Material characteristics.

Process selection requires a broad and extensive knowledge of various materials and the associated manufacturing processes. A good understanding of the capabilities and limitations of the various processes available is an asset to any process planner. Evaluation of alternative processes can also be carried out simultaneously and a logical decision taken with respect to proper selection of the process.

It must be emphasized that the selection of a process is done and evaluated in the context of **product design - material - manufacturing process** in an integrated manner.

Process Selection Parameters

There are several factors which govern the selection of a manufacturing process:

- 1. Shape requirements of the final product *i.e.*, Geometric Form :** Geometric parameters such as solid shape, hollow shape, flat shape, flanged shape, concave shape, convex shape, cylindrical shape, presence of any part feautres such as groove, threaded shape, hole, chamfer, etc. are considered in the selection of a manufacturing process. Each process has its own capabilities and limitations with respect to the production of the above shapes and part features.
- 2. Size or Dimensional requirements :** Some processes are capable of handling parts of small sizes and some processes can handle large sized parts economically and effectively.

3. **Tolerance requirements** : Each manufacturing process has got its own capability with regard to tolerance or accuracy of parts that can be produced using that process *e.g.* grinding process always gives close tolerances when compared with turning process. Depending upon the tolerance specified on the part drawing, suitable machining process is to be selected.
4. **Surface finish requirements** : Each manufacturing process has got its own capability with regard to the surface finish which it can provide on the part machined, *e.g.* reaming process can provide a better surface finish in a hole when compared with drilling process. Similarly cylindrical grinding give a better surface finish, than a plain turning process. Depending on the finish requirements specified on the component drawing, appropriate machining process need to be selected.
5. **Production volume requirements** : The economics of any machining process depends on the production volume, *i.e.*, no. of components required on a weekly, monthly or annual basis as the case may be. Existing order quantity as well as any anticipated future orders and their quantity need to be considered in the process selection. Some of the processes and additional cost incurred in the specialized toolings, jigs and fixtures can be justified only when there is a large volume of production.
6. **Material requirements** : The hardness, and strength characteristics of the material influence the tooling required. To machine hard and tough materials, carbide and ceramic tools are required. If slender or thin materials are machined, proper work holding devices and specially designed jigs and fixtures are required in order to avoid distortion and bending of work pieces during machining. Thus material requirements of the part also influence the appropriate selection of machining process.

MATERIAL SELECTION

Material selection is done by the product designer considering the requirements of the parts designed and the hardness, strength properties and other mechanical characteristics of the material. Cost and availability of the material are also considered. Material should be strong enough and at the same time manufacturing or producibility of the part using the given material and the process are also equally important.

In the initial stages of design, the broad material groups such as ferrous or non-ferrous or other non-metallic materials can be considered. At a later stage specific material in the group can be identified.

In certain products or components specific properties of materials such as fatigue strength, thermal conductivity, electrical properties like conductivity, magnetic permeability and insulation resistance may have to be considered.

Material Selection parameters

- (i) **Functional requirements** : The primary function of the part for which the material is selected is the foremost consideration. A good knowledge of the product application is important. The properties of materials which have a direct bearing on the functional requirement of the part are : fatigue characteristics, strength, hardness, electrical and thermal properties.

- (ii) **Reliability** : Reliability of the materials refers to the consistency with which the material will meet all the products requirement throughout its service life. This is important for trouble-free maintenance of the product during its life time.
- (iii) **Service life durability** : The length of service (years or hours of operation of the product) over which material is able to perform its function satisfactorily.
- (iv) **Aesthetics and appearance** : Factors like colour, texture, lusture, smoothness and finish play an important role in the aesthetics or appearance of the final product.
- (v) **Environmental Factors** : Environmental factors such as temperature, humidity, corrosive atmosphere affects the product and its performance. Hence proper materials which can with stand such environmental effects should be selected and they should be given suitable protective coatings.
- (vi) **Compatibility with other materials during service** : When one type of material is used in combination with another type of material in a product or in an assembly the properties of both types of materials should be compatible and should suit each other. Otherwise deterioration in the performance of the product or assembly such as excessive wear & tear, and corrosion of parts in fitment are likely to take place.
- (vii) **Producibility or manufacturability** : The extent to which the material can be processed effectively and easily using a particular machine tool or process should also be considered in the selection of the material. Machinability of materials for machined components is an important factor.
- (viii) **Cost** : The cost of material is a significant factor in many situations. The availability of the material is equally important. Appropriate material for the product or component is to be selected taking into consideration all the above factors.

SET OF DOCUMENTS REQUIRED FOR PROCESS PLANNING

- (i) Product design and the engineering drawings pertaining to all the components of the product. (*i.e.*, components drawings, specifications and a bill of materials that defines how many of each component go into the product).
- (ii) Machining/Machinability Data Handbook (Tables of cutting speeds, depth of cut, feeds for different processes and for different work materials).
- (iii) Catalogues of various cutting tools and tool inserts.
- (iv) Specifications of various machine tools available in the shop/catalogues of machine tools in the shop (speeds, feeds, capacity/power rating of motors, spindle size, table sizes etc.).
- (v) Sizes of standard materials commercially available in the market.
- (vi) Machine Hr. cost of all equipment available in the shop.
- (vii) Design Data Handbook.
- (viii) Charts of Limits, Fits & Tolerances.
- (ix) Tables showing tolerances and surface finish obtainable for different machining processes.
- (x) Tables of standard cost.
- (xi) Table of allowances (such as Personal Allowance, Fatigue Allowance etc. in % of standard time followed by the company).
- (xii) Process plans of certain standard components such as shafts, bushings, flanges etc.
- (xiii) Handbooks (such as Tool Engineers Handbook, Design Data Handbook).

DEVELOPING MANUFACTURING LOGIC AND KNOWLEDGE :

- (i) Product : design, (*i.e.*, parts requirements) manufacturing process and materials characteristics all must be considered together in an integrated manner while developing a process plan.
- (ii) Identify the datum surface on the component drawings which will form the basis for measurement and inspection of dimensions.
- (iii) Adequate attention must be paid so that the component is properly located and clamped. The accuracy of the machined part and the time taken depend on these factors. This will also avoid any distortion that might occur on the machined component. Three point support (locating pins) are suitable for positioning large flat surfaces.
- (iv) The no. of settings required to machine a part may be reduced to a minimum. Less no. of settings more is the accuracy of the part machined.
- (v) Frequent tool changing can be reduced to a minimum.
- (vi) Rough machining operations must be carried out first before finish machining operations.
- (vii) Identify critical operations and provide for inspection immediately after critical operations.
- (viii) Use appropriate cutting fluid depending on the severity of the operation, the work material and the tool material used.
- (ix) Use of jigs and fixtures are justified when the production quantity is large.

STEPS IN PROCESS PLANNING

- (i) Required operations must be determined by examining the design data and employing basic machining data such as :
 - (a) Holes can be made conveniently on drilling machines.
 - (b) Flat surfaces can be machined easily on milling machines.
 - (c) Cylindrical parts can be made using lathe.Design data can be obtained from the part-drawing or from the finished part design file from the CAD system.
- (ii) The machines required for each operation must be determined. This selection depends on knowledge of machine factors, such as availability of the machine, specifications of machine tools available in the shop, accuracy grade of the m/c, table size, spindle size, speed and feed ranges available, torque, power, machining rate and other size limitations.
- (iii) The required tools for each identified machine or process must be determined. For selection of specialized tools knowledge and prior experience of process planner will be useful.
- (iv) The optimum cutting parameters for each selected tool must be determined. These parameters include cutting speed, feed rate, depth of cut, and type of coolant/lubricant to be used. This determination depends on design data, such as work material, tool material, surface finish specifications and behaviour of cutting tool. Again expertise knowledge and prior experience of process planner and methods engineer will be useful in this regard. Machining data handbooks can also be referred.
- (v) Finally an optimum combination of these machining processes must be determined. The best process plan is the one which minimizes manufacturing time and cost. This provides a detailed plan for the economical manufacturing of the part.

The results of each of these five basic steps can be seen in the final form of the process plan.

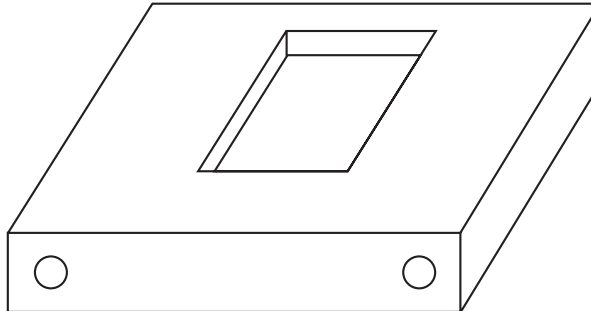


Fig. 2.4 (a) Part to be manufactured

Example 2 : Another example of a process plan for a part to be manufactured is shown below :

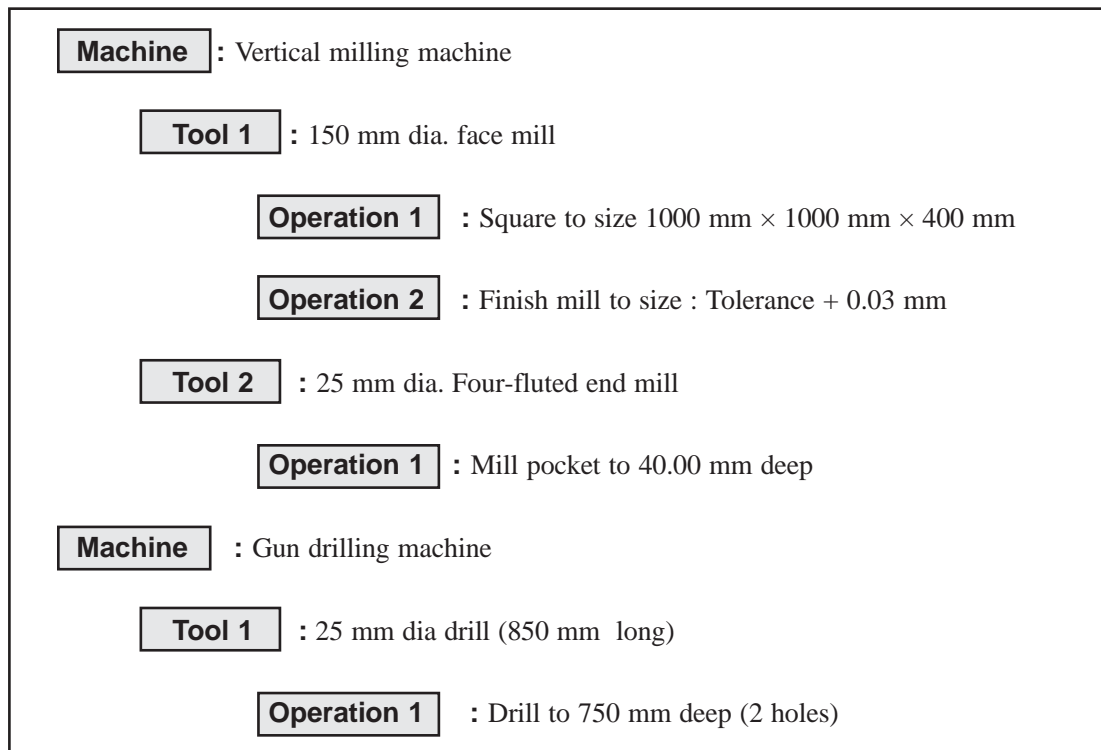


Fig. 2.4 (b) Process plan

Computer Aided Process Planning (CAPP) involves the use of computers to automate this process.

Example 3 : This example refers to process planning for an “axle” (Fig. 2.5) involving Threading operations on the centre lathe using taps and dies. Axle part is shown as assembled in Fig. 2.6.

Operation Plan/Process Plan

No.	Operations	Tools
1.	Chucking (Holding) of workpiece and turning to length, 65 mm	3-jaw chuck, facing tool
2.	Rough and finish turning to 18 ϕ	Pointed turning tool
3.	Drilling of corehole 6.7 ϕ	Twist drill 6.75 N HSS
4.	Chamfering of corehole	Counter-sink 90°
5.	Tapping of M 8 (Internal thread)	M 8 taps (I, II, III), tap wrench
6.	Rechucking of workpiece, turning of part for M 12	Pointed turning tool and facing tool
7.	Cutting of external thread M 12	Die with die holder and collet

Measuring and checking instruments : Vernier caliper, depth gauge, thread plug gauge, ring thread gauge.

The set up sketch for each operation is shown in Fig. 2.7.

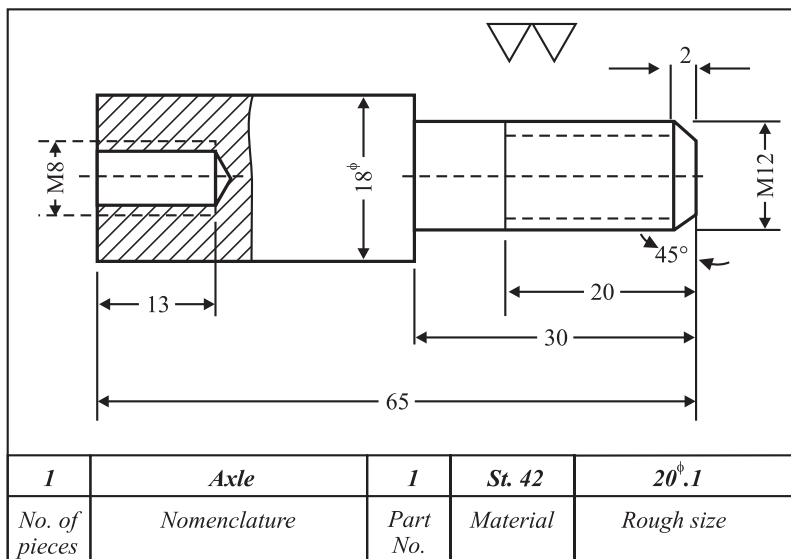


Fig. 2.5. Component drawing of an "Axle".

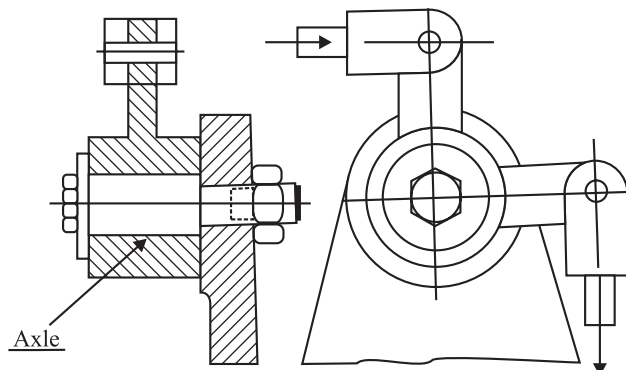


Fig. 2.6. Axle shown assembled.

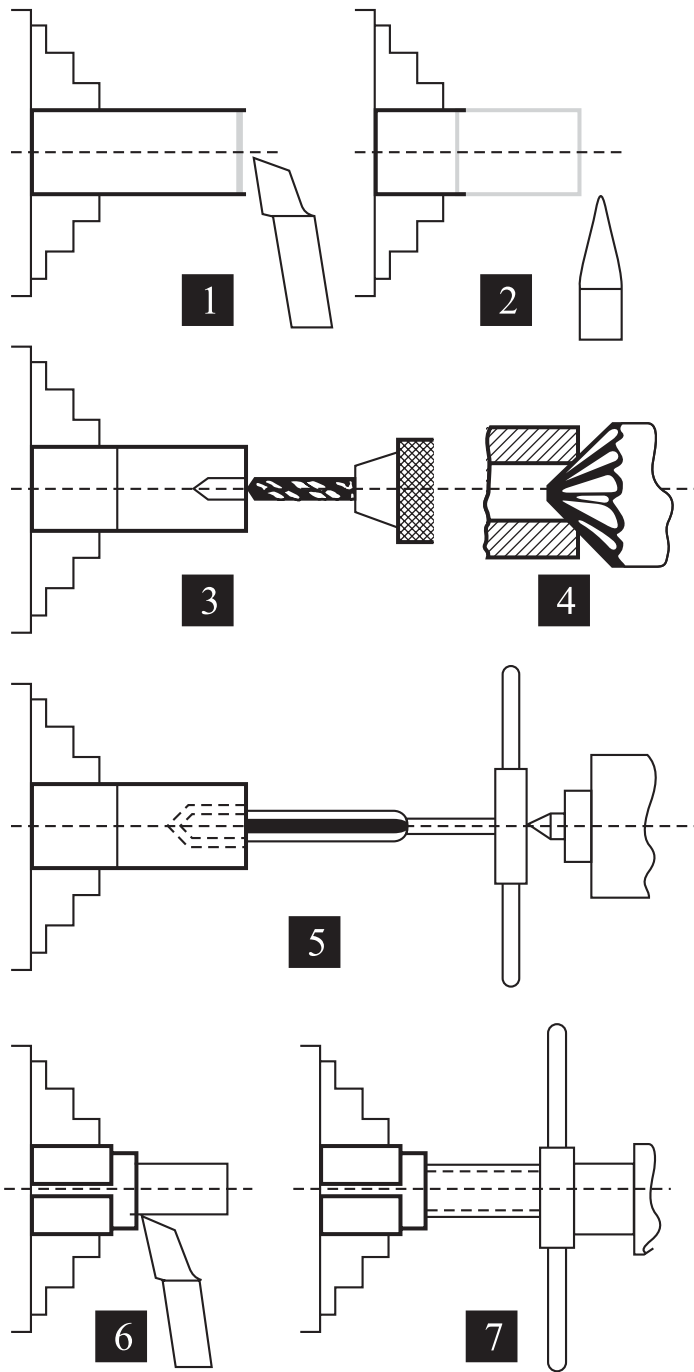


Fig. 2.7. Set up sketch for each operation for manufacturing of Axle.

The sequence of operations is explained below :

<i>Operation No.</i>	<i>Description of operations</i>
1.	Holding of workpiece in 3-jaw chuck and turning to length, 65 mm
2.	Rough turning and finish turning to 18 mm diameter.
3.	Production of internal thread M 8 : Drilling of core hole : For production of internal thread M 8 drilling of core hole is to be done. The core diameter amounts to 6.38 mm only. In the beginning of internal thread cutting burrs are likely to form. For this reason, it is necessary that core-hole must be drilled bigger than the core diameter of the thread.

Table : Tap Diameters for Thread Coreholes.

Metric thread (M.....)

Thread	M 3	M 3.5	M 4	M 5	M 6	M 8	M 10	M 12	M 14	M 16	M 18	M 20	M 22	M 24	M 27
Thread holes for steel	2.5	2.9	3.3	4.2	5.0	6.7	8.4	10.0	11.75	13.75	15.25	17.25	19.25	20.75	23.75
Cast iron, brass	2.4	2.8	3.2	4.1	4.8	6.5	8.2	9.9	11.5	13.5	15	17	19	20.5	23.5

(Fig. 2.8) As per Table given below the core hole must be drilled to 6.70 mm.

4. **Counter sinking of core hole :** The core-hole is counter sunk with a 90° countersink bit, so that the tap cuts in easily and formation of burrs is avoided.
5. **Cutting of internal thread :**
Selection of Taps for cutting of internal threads is to be done. In the selection of taps, the material of the workpiece, shape and length of thread have to be taken into account. The taps for triangular threads are standardized and are manufactured of tool steel or HSS. The threads on the tap are machined and ground. Since only one piece is required Hand Taps (M 8) in set of three (Rougher, Intermediate and Finisher) can be used for thread cutting in blind holes. (Fig. 2.9).

Table : Cutting Speeds (in m/min) for Thread Cutting.

<i>Work material</i>	<i>Thread cutting tool of</i>	
	<i>Tool steel</i>	<i>High-speed steel</i>
Unalloyed structural steel	5	12
Structural alloy steel	—	6
Cast iron	5	9
Brass	10	15
Aluminium alloy	16	25

Cutting of Internal Thread

Thread cutting will be done manually (by hand) with No. I tap and then the machine will be engaged. The sleeve will be adjusted regularly in conformity with the feed of the tap. The succeeding tap will be some what screwed in by hand and then the tap holder will be used.

During the cutting of internal thread it should be ensured that

- (a) Taps must be sharp, otherwise the thread flanks become rough and cracks are developed.
- (b) The work piece runs concentric to avoid formation of oblique threads.
- (c) Hand taps are inserted in proper sequence of the set (i.e., I, II and III) Fig. 2.9.
- (d) Suitable lubricants are used to reduce friction and to get clean thread flanks.

Lubricants for thread cutting

<i>Work Material</i>	<i>Lubricant</i>
Unalloyed structural steel	Cutting oil
Alloy steel	Cutting oil, turpentine, kerosene
Cast iron	Dry or abundant oil
Brass and Bronze	Cutting oil
Aluminium alloy	Cooling oil (emulsion), kerosene

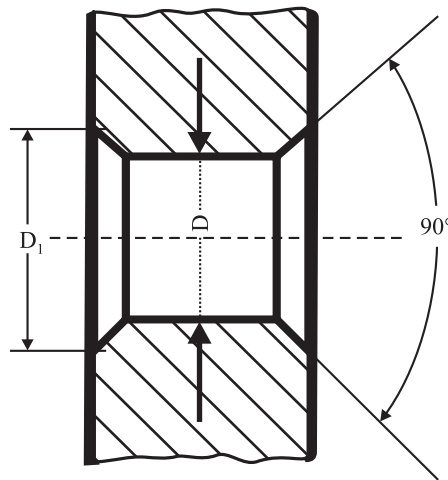


Fig 2.8. Preparation of the Core hole

D : Core Diameter of thread **D₁ :** External Diameter (i.e., Maximum Dia.) of thread

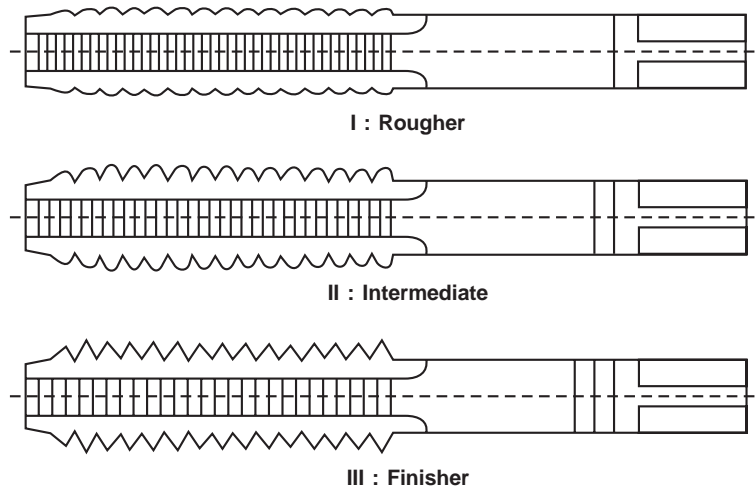


Fig 2.9. Hand taps in set of three.

- 6. Holding of workpiece, turning of part for M12.

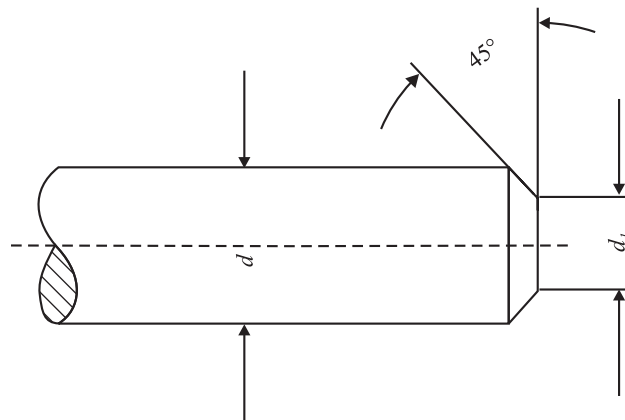


Fig. 2.10 : Preparing the bolt end

d : External diameter of the thread = 12 mm

d₁ : Core diameter of the thread = 11.85 mm

Preparing the bolt end : (Fig. 2.10). Since burrs are likely to form, the thread part of the bolt end is turned to 11.85 mm diameter, *i.e.*, external diameter reduced by 10% of the pitch (pitch = 1.5 mm; 12 mm – 0.15 mm = 11.85 mm). The chamfer enables an easy first cut Fig. 2.10.

7. **Production of male thread (External Thread) M12.**

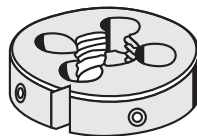
For this **selection of threading** die is to be done. A die of M12 is required. Threading dies are standardized and are generally made of tool steel or H.S.S Fig. 2.11.

Cutting of External Thread M12.

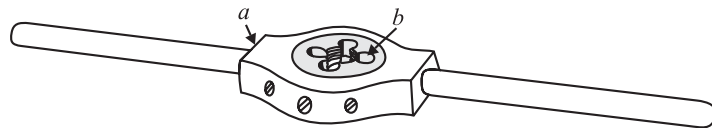
The first turns of the thread are cut by hand manually. After that, the machine will be engaged with proper no. of revolutions. The sleeve must be adjusted regularly. Use coolant/lubricant regularly.

During cutting or external thread it should be ensured that

- (a) Face of the die must have good contact with the collet or die holder Fig. 2.11. The workpiece must run concentric, the threading die has to be applied in a straight way, otherwise the thread will become elliptical.



Threading die



Die with holder (a) Die holder, (b) die

Fig. 2.11

- (b) Blunt threading dies create rough and irregular flanks. Hence ensure that the die is sharp.
 (c) Chips in the chip hole damage the thread flanks. Withdraw the die now and then to ensure that the chips flow away.
 (d) Lubrication has to be applied regularly.

SELECTION OF COST OPTIMAL PROCESS

Two different types of processes can be used for the same job. The processes can be compared and optimum process selected with the help of break-even charts.

Break-even charts : Break-even charts give the production engineer a powerful tool by which feasible alternative processes can be compared and the process which gives minimum cost can be selected. The fixed and variable costs for two alternative processes are plotted on a graph to a suitable scale as shown in Fig. 2.12.

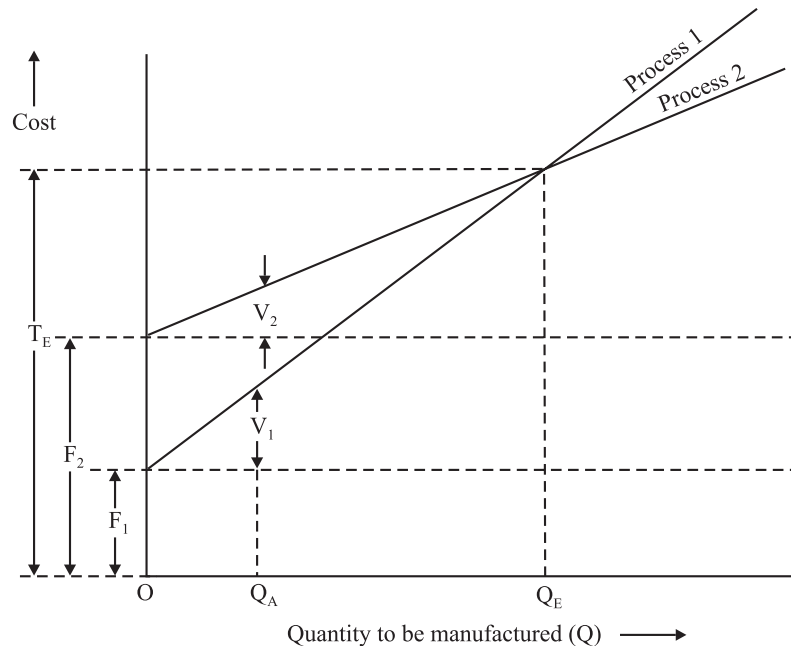


Fig. 2.12 Break-even chart for two processes

- F_1 = Fixed costs for process (1)
 - F_2 = Fixed costs for process (2)
 - V_1 = Variable costs for process (1)
 - V_2 = Variable costs for process (2)
- } at quantity Q_A
- Q_E = Break-even quantity
 - T_E = Total costs of manufacture at quantity Q_E

For each process generally the variable cost is a linear function of the quantity manufactured. Therefore, once the fixed costs have been plotted, only one value for the variable costs is required at some value Q_A and the total cost lines can be drawn.

Where these lines intersect is known as the break-even point, *i.e.*, the point where the total cost of manufacture of quantity Q_E is same for both process (1) and process (2). The break-even chart tells us to :

Use process (1) if the quantity to be manufactured $\leq Q_E$

Use process (2) if the quantity to be manufactured $\geq Q_E$

The value of Q_E can be scaled directly from the chart with sufficient accuracy, although it can also easily be calculated.

Example 1 : A component can be produced with equal ease on either a capstan lathe or on a single spindle cam operated automatic lathe. Find the break-even quantity Q_E if the following information is known.

	<i>Capstan Lathe</i>	<i>Automatic Lathe</i>
(a) Tooling cost	Rs. 30.00	Rs. 30.00
(b) Cost of cams	—	Rs. 150.00
(c) Material cost/Component	Rs. 0.25	Rs. 0.25
(d) Operating labour cost	Rs. 2.50/hour	Rs. 1.00/hour
(e) Cycle time/Component	5 minutes	1 minute
(f) Setting up labour cost	Rs. 4.00/hour	Rs. 4.00/hour
(g) Setting up time	1 hour	8 hours
(h) Machine overheads (setting and operating)	300 % of (d)	1000 % of (d)

Solution

Capstan lathe : Overheads = $\frac{300}{100} \times 2.50 = \text{Rs. } 7.50/\text{hour}$

$$\begin{aligned} \text{Fixed Costs} &= \text{tooling cost} + \text{setting-up cost} \\ &= 30.00 + 1(4.00 + 7.50) \\ &= 30.00 + 11.50 = \text{Rs. } 41.50 \\ &\approx \text{Rs. } 42 \end{aligned}$$

$$\begin{aligned} \text{Variable costs/Component} &= \left(2.50 \times \frac{5}{60} \right) + 0.25 + \left(7.50 \times \frac{5}{60} \right) \\ &= 0.21 + 0.25 + 0.63 = \text{Rs. } 1.09 \end{aligned}$$

$$\text{Variable costs/1000 components} = \text{Rs. } 1090.00$$

Automatic lathe : Overheads = $\frac{1000}{100} \times 1.00 = \text{Rs. } 10.00/\text{h}$

$$\text{Fixed costs} = \text{tooling cost} + \text{cam cost} + \text{setting-up cost}$$

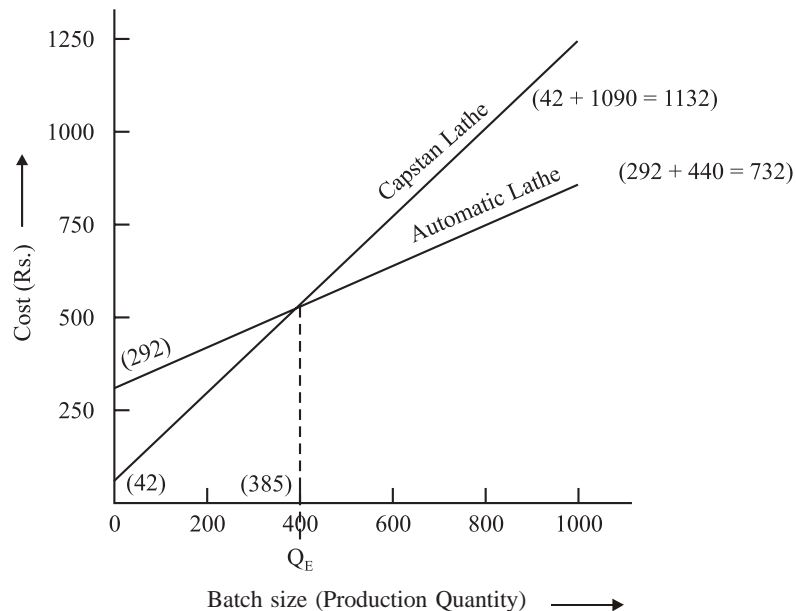


Fig. 2.13 : Break-even chart.

$$\begin{aligned}
 &= 30.00 + 150.00 + 8 (4.00 + 10.00) \\
 &= 180.00 + 112.00 = \text{Rs. } 292.00 \\
 \text{Variable costs/Component} &= \left(1.00 \times \frac{1}{60} \right) + 0.25 + \left(10.00 \times \frac{1}{60} \right) \\
 &= 0.02 + 0.25 + 0.17 = \text{Rs. } 0.44
 \end{aligned}$$

Variable costs/1000 components = Rs. 440.00.

These costs can now be plotted on a break-even chart (Fig. 2.13) to find the value of Q_E .

Q_E is scaled from the break-even chart (Fig. 2.13) and found to be 385. If the batch size to be manufactured is equal to or less than 385 use the capstan lathe.

If the batch size to be manufactured is equal to or greater than 385 use the automatic lathe. The above is the graphical method of determining Break-even Quantity.

In this example no account was taken directly of the costs of depreciation and interest charges. The cost accountant’s methods of dealing with these charges will be determined by circumstances.

If preferred, the break-even quantity Q_E can be calculated numerically thus :

Total cost of producing a quantity x on the capstan lathe
 $= 41.50 + 1.09 x$

Total cost of producing a quantity x on the automatic lathe
 $= 292.00 + 0.44 x$

When x is equal to Q_E the total costs for each machine must equal.

$$\therefore 41.50 + 1.09 x = 292.00 + 0.44 x$$

$$1.09 x - 0.44 x = 292.00 - 41.50$$

$$\therefore 0.65 x = 250.50$$

$$x = \frac{250.50}{0.65} = 385 \text{ at the break-even point.}$$

Thus Break-even chart or break-even analysis can be made to select the cost optimal process.

Example 2 : A component can be produced will equal facility using either a numerically controlled milling machine, or an operator controlled milling machine (conventional machine).

- (a) Which process should be chosen for minimum costs if two components only are required ? (Assume no special tooling for the conventional machine and hence no fixed costs, but that it is a toolroom universal milling machine with high overheads.)
- (b) Which process should be chosen for minimum costs if a batch of 100 components is required ? (Assume special tooling such as fixture and gauges are required for the conventional machine, which is a plain milling machine on a production line).

The following cost information is known.

	<i>Situation (a)</i>		<i>Situation (b)</i>	
	<i>N/c machine</i>	<i>Conventional machine</i>	<i>N/c machine</i>	<i>Conventional machine</i>
Fixed cost	Rs. 80	—	Rs. 80	Rs. 300
Labour/part	Rs. 1.50	Rs. 12.50	Rs. 1.50	Rs. 0.35
Material/part	Rs. 1.00	Rs. 1.00	Rs. 1.00	Rs. 1.00
Overheads/part	Rs. 3.00	Rs. 30.00	Rs. 3.00	Rs. 2.25

Solution : Situation (a)

Variable costs/part for N/c machine = $1.50 + 1.00 + 3.00 = \text{Rs. } 5.50$

Variable cost/part for conventional machine = $12.50 + 1.00 + 30.00 = \text{Rs. } 43.50$

The costs can now be plotted on a break-even chart (Fig. 2.14)

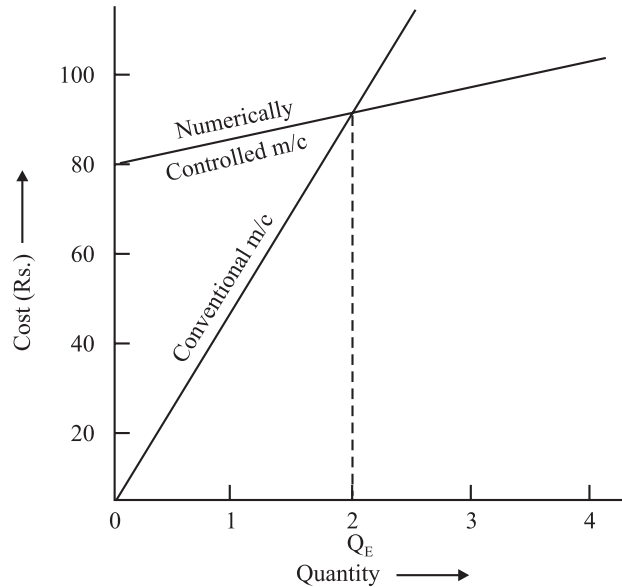


Fig. 2.14 : Break-even chart

Q_E is equal to approximately 2.2 components.

The conventional machine should be chosen if two components only are required.

Situation (b)

Variable costs/part for N/c machine = $1.50 + 1.00 + 3.00 = \text{Rs. } 5.50$

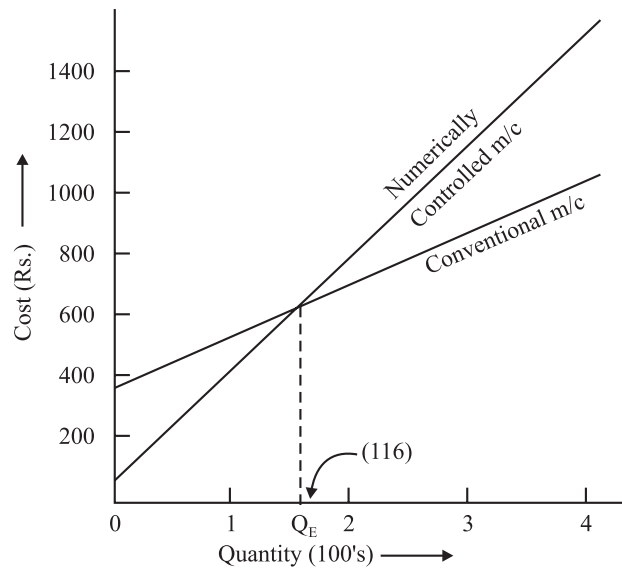


Fig. 2.15 : Break-even chart.

Variable costs/100 parts for N/c machine = Rs. 550.00

Variable costs/part for conventional machine = $0.35 + 1.00 + 2.25 = \text{Rs. } 3.60$

Variable costs/100 parts for conventional machine = Rs. 360.00

The costs can now be plotted on a break-even chart (Fig. 2.15) to find the value of Q_E .

Q_E is equal to approximately 116 components.

The numerically controlled milling machine should be chosen if more than 100 components are required. The above problem can be solved analytically also.

BREAK EVEN POINT, BREAK EVEN CHART AND BREAK EVEN ANALYSIS : Instructional Objectives

After studying this unit the students will be able to :

- (1) Distinguish between fixed costs and variable costs.
- (2) Calculate hourly cost of running and maintenance of machines.
- (3) Draw break-even chart from given data and select the best process.
- (4) Select the most economical method for the manufacture of a component from the available alternatives.

The total cost of running and maintenance of machines can be divided into two parts—Fixed costs and Variable costs. The meaning of fixed costs and variable costs, in general is given below.

Fixed costs : The fixed costs are the items of expenditure which remain more or less constant irrespective of the volume of production. Some important items under fixed costs are depreciation of plant and machinery and building, interest on capital, supervisory charges, cost of lighting, heating and cleaning the works, operator charges, rent of building etc.

Variable costs : Variable costs are those items of expenditure which vary with the volume of production. Some important items under variable costs are direct material cost, cost of power/fuel consumed, cost of tools used, cost of consumable stores, repair and maintenance charges, storage charges, etc.

Calculation of hourly cost of running and maintenance of machines can be done on the basis of fixed costs and variable costs.

1. Fixed Costs

- (i) **Depreciation :** Depreciation is defined as the reduction in the value of an asset, machinery, equipment or building with passage of time due to various reasons, such as wear and tear, and obsolescence. Whether we use the machine or not its value is decreasing with passage of time. Depreciation is computed and accounted for in calculating the hourly cost of running and maintenance of machines. There are different methods of calculating and apportioning depreciation charges.
- (ii) **Interest on capital amount :** Interest on capital amount invested in the purchase of the machine is also considered in calculating hourly cost of running the machine. The rate of interest is that which the capital amount would have yielded if that amount is invested in a bank. The interest on capital is constant whether the machine is being used or not.
- (iii) **Supervisory charges :** Supervisory charges include the wages of supervisors, foremen, inspectors etc., who supervise the production. These wages are calculated for a year for a particular department. The supervisory charges are distributed over the total number of machine-hours available in a year in that department.
- (iv) **Operator charges :** If the operator of the machine is paid on monthly basis his wages are also included in the fixed costs and considered in calculating the hourly charges of running the machine. (However, if the operator is paid on piece rate basis, then the operator charges form a part of variable costs, since the operator charges are proportional to the number of pieces produced).
- (v) **Rent of building :** The rent of space occupied by the machine is independent of the volume of production. The proportion of rent of building considered in hourly cost of running of machine is calculated by dividing the rent of building space by machine-hours available in one month.

2. Variable Costs

- (i) **Power (or energy) or fuel consumed** : Cost of power or fuel consumed in running the machine varies with the volume of production. The total cost of power is calculated at the end of each month and is distributed over various departments according to the actual power consumed by each department. The power charges are then distributed on each machine in the department and hourly cost of power consumed is calculated. The total power cost includes the expenses made on salary of the power plant-in-charge and other staff, expenses for repair and maintenance of power plant, depreciation of plant and machinery in power house and cost of coal and fuel (if used) or electricity bill.
- (ii) **Repair and maintenance charges** : The repair and maintenance charges of a machine generally depend on the extent of the usage of the machine. Higher is the volume of production, higher will be the wear and tear and hence more expenses on repair and maintenance. If the repair of the machinery is got done from some outside parties, then the charges are taken from the repairers bill. But in all medium and large organisations, a separate maintenance department looks after the work of repair and maintenance. In such cases, a record of all the expenditure involved in the maintenance of equipment is made and the total cost of repair and maintenance over a year is computed. This cost divided by the number of machine-hours available in one year gives the hourly cost of repair and maintenance for that machine.
- (iii) **Consumable stores and other charges** : The expenditure incurred on consumables like lubricants, coolants, oils, cotton waste and small tools depends on the volume of production. The cost of clerical work involved in the operation of stores, cost of storage space required and cost of labour required for handling the materials etc., are dependent on the volume of production and form a part of variable expenses.

Total cost of the consumables and services are added and apportioned to various departments, based on the consumable and services used up by various departments, or on the basis of direct labour cost or direct material cost. This is then distributed over various machines in the department.

HOURLY COST OF RUNNING AND MAINTENANCE OF A MACHINE

$$= \frac{\text{Fixed costs}}{\text{Machine life in hours}} + \text{Variable costs per hour}$$

The hourly cost of running and maintenance of a machine has to be calculated before we can calculate the total cost of any component requiring machining operations.

The cost of using a particular machine for one component is given by :

$$C = T \times R$$

where

C = Cost of using a particular machine for making one component.

T = Machine hours required to make one component.

R = Hourly rate of running and maintenance of machine.

BREAK-EVEN POINT, BREAK-EVEN CHART AND BREAK-EVEN ANALYSIS

- (1) **Break-even point (BEP)** represents the production quantity for which the total cost of producing the goods equals the total sales price. At break-even point there will be neither any profit nor any loss to the manufacturer.

If	$Q = \text{Quantity at BEP}$
	$F = \text{Fixed costs}$
	$V = \text{Variable cost per unit produced}$
	$S = \text{Selling price per unit}$
Then	$F + (Q \times V) = S \times Q$
	$Q = \frac{F}{S - V}$

(2) **Break-even chart** is a graphical representation of inter-relationship between quantity produced, cost of producing and sales return. The total cost of production (fixed cost + variable cost) and total sales return are plotted against quantity produced. The intersection of the total cost and total sales return lines gives the break-even point.

Uses of Break-even Chart

Break-even chart indicates the profit or loss at varying levels of production activity. From Fig. 2.16 we see that there will be loss to the organisation if the quantity produced is less than Q but if the quantity produced is more than Q , there will be profit.

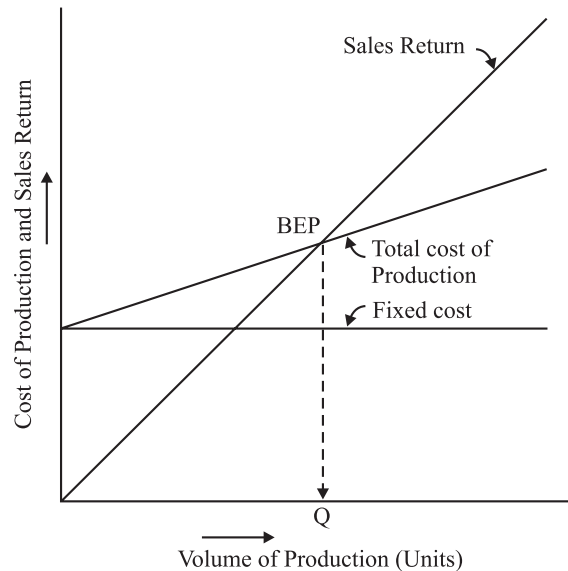


Fig. 2.16

3. Break-even Analysis

Break-even charts are also used for comparing the cost of producing a product by different manufacturing processes. The total costs for two alternative processes are plotted on a graph against quantity to be produced. The point where these two lines intersect is known as break-even point (Fig. 2.17). The break-even chart tells us :

- (i) Use process A if the quantity to be manufactured is less than quantity at BEP.
- (ii) Use process B if the quantity to be manufactured is more than quantity at BEP.

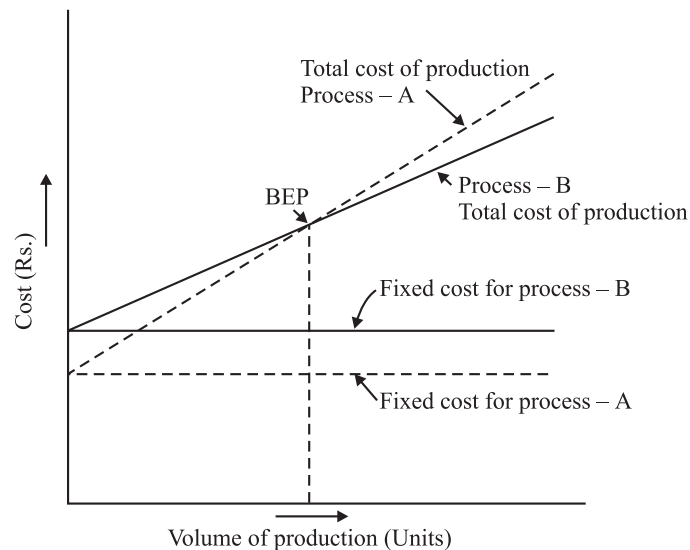


Fig. 2.17

ILLUSTRATIVE EXAMPLES ►

Example 1 : In a small factory making toys, the fixed overhead costs are Rs. 5,000 per month and the variable cost is Rs. 4 per piece. The selling price is Rs. 6 per piece. Estimate the minimum monthly production so that the factory may not suffer any loss.

Solution :

$$\text{Fixed cost} = \text{Rs. } 5,000$$

$$\text{Variable cost} = \text{Rs. } 4 \text{ per piece}$$

$$\text{Selling price} = \text{Rs. } 6 \text{ per piece}$$

$$\text{Let the required minimum production} = P \text{ units}$$

$$\text{Total cost of producing } P \text{ units} = \text{Fixed cost} + \text{Variable cost}$$

$$= 5,000 + (P \times 4)$$

$$= 5,000 + 4P$$

$$\text{Total selling price of } P \text{ units} = 6 \times P$$

Now for no profit no loss conditions, the total cost of producing P units should be equal to total sales return

$$5,000 + 4P = 6P$$

$$P = 2,500$$

Therefore, to avoid any loss to the factory, minimum monthly production should be 2,500 pieces.

More than 2,500 pieces per month must be manufactured and sold so that the company can earn profit.

Example 2 : A factory has three sections in a machine shop. During one calendar year the following details are available :

- (i) Depreciation and rent of building Rs. 8,000

(ii) Supervisory charges	Rs. 20,000
(iii) Indirect labour and indirect materials	Rs. 7,000
(iv) Insurance charges	Rs. 5,000
(v) Other charges (given below)	

<i>Item of expenditure</i>	<i>Section I</i>	<i>Section II</i>	<i>Section III</i>
Depreciation of machines	Rs. 5,000	Rs. 7,000	Rs. 4,000
Cost of power consumed	Rs. 3,000	Rs. 5,000	Rs. 2,000
Area occupied as percentage of total area	40%	20%	40%
M/C hours worked	8,000	25,000	10,000
Maintenance charges	Rs. 2,000	Rs. 3,000	Rs. 1,000

Find out the machine-hour rate for each section if the common fixed expenses are to be apportioned on the basis of floor space occupied by each section.

Solution : The total expenses for Section I are as follows :

- (i) Common fixed expenses such as depreciation and rent of building, supervisory charges, indirect labour and indirect materials and insurance charges are charged on the basis of floor area occupied.

$$= (8,000 + 20,000 + 7,000 + 5,000) \times \frac{40}{100}$$

$$= \text{Rs. 16,000 per year}$$

(ii)

Depreciation of machines	=	Rs. 5,000
Power charges	=	Rs. 3,000
Maintenance charges	=	Rs. 2,000
Total expenses	=	16,000 + 5,000 + 3,000 + 2,000
	=	Rs. 26,000 per year.

Machine-hours worked during one year = 8,000

$$\text{Machine-hour rate for Section I} = \frac{26,000}{8,000} = \text{Rs. 3.25}$$

For Section II :

$$\text{Total cost} = (8,000 + 20,000 + 7,000 + 5,000) \times \frac{20}{100} + (7,000 + 5,000 + 3,000)$$

$$= \text{Rs. 23,000 per year}$$

Machine-hours worked during one year = 25,000

$$\text{Machine-hour rate for Section II} = \frac{23,000}{25,000} = \text{Rs. 0.92}$$

Similarly calculate the machine-hour rate for Section III = Rs. 2.30

Example 3 : A manufacturing concern purchased two identical machines each for Rs. 15,000. If depreciation of the machines is on the basis of machine-hours and if the two machines are to share the

rent, lighting, water charges etc., proportional to floor area occupied by the machine, workout the machine-hour rate from the given data :

Scrap value of each machine after 10 years	=	Rs. 2,500
Machine-hours/year/machine	=	2,200
Power consumption per hour per machine	=	10 Units
Rate per Unit of power consumed	=	Rs. 3
Maintenance and repair charges/year/machine	=	Rs. 150
Overhead charges per machine per year	=	Rs. 160
Workshop rent per year	=	Rs. 12,000
Lighting, water charges per year	=	Rs. 600
Floor space occupied by each machine	=	20 per cent of floor space of works

Solution : We will make the calculations for one machine.

The fixed costs are :

- (i) Depreciation,
- (ii) Maintenance and repair charges,
- (iii) Overhead charges,
- (iv) Workshop rent,
- (v) Lighting, water charges etc.

The variable costs are :

- (i) Power consumed

Fixed costs :

- (i) Depreciation : Initial cost = Rs. 15,000
 Scrap value = Rs. 2,500
 Life of m/c = 10 years
 Depreciation per year = $\frac{15,000 - 2,500}{10} = \frac{12,500}{10} = \text{Rs. } 1,250$
- (ii) Maintenance and repair charges/year = Rs. 150
- (iii) Overhead charges/year = Rs. 600
- (iv) Workshop rent/year = Rs. 12,000
- (v) Water and lighting charges/year = Rs. 600

Now the machine occupies 20 percent of floor space of works. Share of rent and lighting charges for one machine

$$= \frac{20}{100} \times (12,000 + 600) = \text{Rs. } 2520 \text{ per year}$$

$$\text{Fixed costs per year} = 1,250 + 150 + 600 + 2520 = \text{Rs. } 4520$$

$$\text{No. of machine-hours per year} = 2,200$$

$$\text{Fixed costs per machine-hour} = \frac{4520}{2,200} = \text{Rs. } 2.10$$

Variable costs

$$\text{Power consumed per hour} = 10 \text{ Units}$$

$$\text{Rate per Unit of power} = \text{Rs. } 3$$

$$\text{Cost of power consumed per hour} = 10 \times 3 = \text{Rs. } 30$$

$$\text{Variable costs per machine-hour} = \text{Rs. } 30$$

$$\begin{aligned} \text{Now machine-hour rate} &= \text{Fixed cost per m/c hour} + \text{Variable costs per m/s hour} \\ &= 2.10 + 30.00 = \text{Rs. } 32.10 \end{aligned}$$

Example 4 : In a factory fixed overhead charges are Rs. 45,000 and the variable overhead charges are Rs. 2.50 per article. The factory is producing 45,000 articles per month under normal conditions. Find :

- (i) Overhead cost per article under normal conditions.
- (ii) If the production drops to 80 percent, calculate the charges that remain uncovered.
- (iii) If the production increases to 125 percent, by what amount these charges will be over-recovered.

Take the overhead rate per article the same as during normal production, in both the cases.

Solution : (i) Under normal conditions :

$$\begin{aligned} \text{Rate of overheads per article} &= \text{Fixed overheads per article} + \text{Variable overheads per article} \\ &= \frac{45,000}{45,000} + 2.50 = \text{Rs. } 3.50 \text{ per article.} \end{aligned}$$

(ii) If the production drops to 80 percent of normal production

$$\text{No. of articles produced} = \frac{45,000 \times 80}{100} = 36,000$$

The total amount spent on producing 36,000 articles

$$\begin{aligned} &= \text{Fixed cost} + \text{Variable costs} \\ &= 45,000 + (36,000 \times 2.5) \\ &= \text{Rs. } 1,35,000 \end{aligned}$$

Amount recovered as overheads @ Rs. 3.50 per article

$$= 36,000 \times 3.50 = \text{Rs. } 1,26,000$$

$$\text{So, the amount that remains uncovered} = 1,35,000 - 1,26,000 = \text{Rs. } 9,000$$

(iii) If the production increases to 125 percent of normal production

$$\text{Number of articles produced} = 45,000 \times \frac{125}{100} = 56,250$$

$$\text{Amount spent on producing 56,250 articles} = 45,000 + (56,250 \times 2.50) = \text{Rs. } 1,85,625$$

$$\text{Amount recovered @ Rs. 3.50 per article} = 56,250 \times 3.50 = \text{Rs. } 1,96,875$$

$$\text{Amount that is over-recovered} = 1,96,875 - 1,85,625 = \text{Rs. } 11,250$$

Example 5 : The fixed costs for a factory for the year 2003–04 are Rs. 1,50,000 and the variable cost is Rs. 10 per unit produced. The selling price per unit is Rs. 25, calculate the break-even quantity.

Solution :

$$\begin{aligned}\text{Fixed costs} &= \text{Rs. } 1,50,000 \text{ per year} \\ \text{Variable cost} &= \text{Rs. } 10 \text{ per unit} \\ \text{Selling price} &= \text{Rs. } 25 \text{ per unit}\end{aligned}$$

The break-even quantity can be calculated analytically as well as by plotting a graph.

(i) Analytical method :

$$\begin{aligned}\text{Let the break-even quantity} &= X \text{ units} \\ \text{Total cost of producing } X \text{ units} &= 1,50,000 + 10 X \\ \text{Return from sale of } X \text{ units} &= 25 X\end{aligned}$$

At break-even point

$$\begin{aligned}1,50,000 + 10 X &= 25 X \\ X &= 30,000 \text{ units.}\end{aligned}$$

(ii) Graphical method :

The total cost of producing and sales return is plotted against the quantity produced Fig. 2.18. The quantity at which the two lines intersect gives the break-even point. From graph we see that the lines intersect at 30,000 units which gives break-even quantity.

Example 6 : The following information is available for two machines in a manufacturing unit :

<i>Item of expenditure</i>	<i>Machine I (Capstan lathe)</i>	<i>Machine II (Automatic lathe)</i>
(i) Tooling cost	Rs. 300	Rs. 1,800
(ii) Operating labour cost per hour	Rs. 5	Rs. 1
(iii) Cycle time per piece	5 min.	1 min.
(iv) Setting up cost	Rs. 20	Rs. 150
(v) Overheads	Rs. 30	Rs. 250
(vi) Maintenance cost per hour	Rs. 6	Rs. 25
(vii) Power charges per hour	Rs. 2	Rs. 4

Draw the break-even chart for the two machines and find out break-even quantity. Also find out which process is suitable for producing 4,000 items.

Solution : This is a problem on comparison of cost of manufacturing the components on two different machines or processes.

(i) Machine I : (Capstan lathe)

$$\begin{aligned}\text{Fixed cost} &= \text{Tooling cost} + \text{Set-up cost} + \text{Overheads} \\ &= 300 + 20 + 30 = \text{Rs. } 350 \\ \text{Variable cost} &= \text{Operating labour cost} + \text{Maintenance charges} + \text{Power charges} \\ &= \frac{5 \times 5}{60} + \frac{5 \times 6}{60} + \frac{5 \times 2}{60} = \text{Rs. } 1.08\end{aligned}$$

(ii) Machine II :

$$\begin{aligned}\text{Fixed costs} &= \text{Tooling cost} + \text{Set-up cost} + \text{Overheads} \\ &= 1,800 + 150 + 250 = \text{Rs. } 2,200\end{aligned}$$

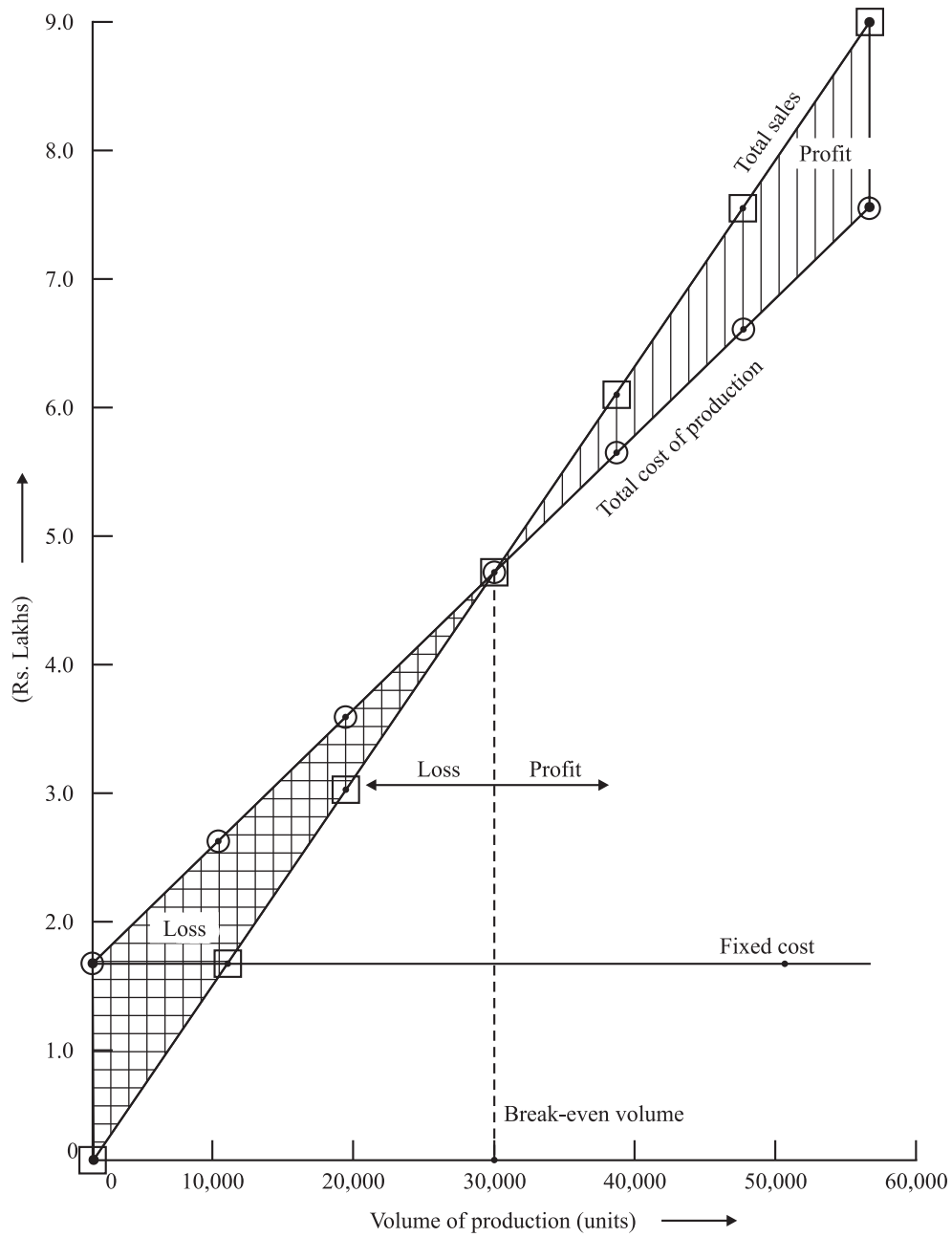


Fig. 2.18 Break-even chart

$$\text{Variable cost} = \frac{1 \times 1}{60} + \frac{1 \times 25}{60} + \frac{1 \times 4}{60} = \text{Rs. } 0.50$$

The break-even chart is shown in Fig. 2.19.

$$\text{Break-even quantity } Q_E = 3,190$$

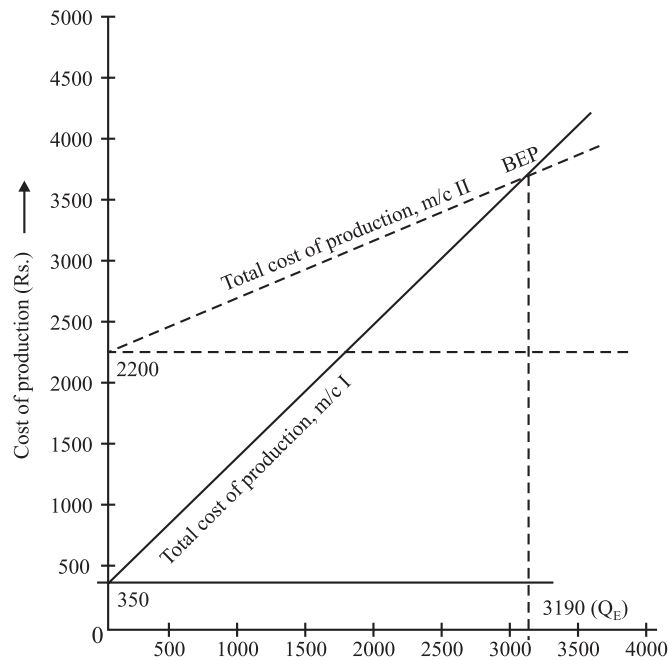


Fig. 2.19. Volume of production (units)

Now from the chart we see that machine I is economical if quantity to be produced is less than Q_E and machine II is economical if quantity to be produced is more than Q_E .

To produce 4,000 units, machine II is economical.

EVALUATIVE QUESTIONS ► PROCESS PLANNING

1. Give the main characteristics of job, batch and mass production.
2. What do you understand by Process Planning ?
3. Give a procedure for process planning for the manufacture of a component in machine shop.
4. Write short notes on :
 - (a) Batch production
 - (b) Calculation of material quantity required
 - (c) Uses of a process sheet.
5. Explain the steps involved in calculation of man-hours and machine-hours availability.
6. Name the type of production activity (Job, batch or mass production) for the following :
 - (a) Press tools
 - (b) Nuts and Bolts
 - (c) Fertilizers
 - (d) Bricks
 - (e) Readymade shirts
 - (f) Pencils
 - (g) Tractors
 - (h) Cars
 - (i) Cloth
 - (j) Watches
 - (k) Furniture
7. The following data is available for a machine shop :

(a) No. of machines	6
(b) No. of working days/month	25
(c) Working hours per day	8 (one shift only)
(d) Overtime allowed per day	1.5 hours
(e) Absenteeism	10%
(f) Repair and maintenance allowance	5%

Calculate the net available machine-hours in one month.

8. What factors are taken into consideration in product design ?
9. What are the steps involved in process design ?
10. What is process design and what are the factors affecting process design ?
11. Draw a graph connecting “product variety” and “production quantity” for different types of production.
12. What are the advantages of ‘Standardization’ ?
13. What are the steps involved in “Process Planning” ?

14. What is a "Route Sheet" ?
15. What are the two approaches to Process Planning in the context of CAPP (Computer Aided Process Planning) ? Explain them clearly.
16. What factors are taken into consideration in Process Selection ?
17. What factors are taken into consideration in Machine Selection ?
18. What are the process selection parameters ?
19. What are the various parameters considered in the material selection ?
20. What are the documents required for Process Planning ?
21. What are the different factors considered in developing a manufacturing logic ?
22. What are the basic steps in Process Planning ?

EVALUATIVE QUESTIONS ► BREAK-EVEN POINT AND BREAK-EVEN CHART

1. (a) What do you understand by hourly cost of running a machine ?
(b) What are the various cost elements considered in calculating the hourly cost of running a machine ?
2. Define break-even point and how to calculate break-even quantity ?
3. What is a break-even chart ? What are the uses of break-even chart ?
4. Explain the following :
(a) Fixed costs
(b) Variable costs
(c) Break-even point
5. A component can be made either on an ordinary lathe or on an automatic lathe. The time taken in first case is $1\frac{1}{2}$ hours per piece and overheads are 30 percent of labour cost. In the second case, the time taken is 30 minutes per item and overheads are 200 per cent of labour cost. If the material cost is Rs. 20 per piece and labour charges are Rs. 5 per hour, compare the total cost in both the cases.
6. A factory has 15 lathes of same make and 15 shapers of same make and capacity. Lathes occupy 30 m² floor area while shapers occupy 15 m² floor area. During one calendar year, factory expenses are as follows :

	Rs.
(i) Building rent and depreciation	5,000
(ii) Indirect labour and material costs	15,000
(iii) Insurance charges	2,000
(iv) Depreciation charges of lathes	5,000
(v) Depreciation charges of shapers	3,000
(vi) Power consumption for the lathes	2,000
(vii) Power consumption for the shapers	1,000