

PART I - INTRODUCTION TO ECONOMICS AND COST

1.1 Introduction

Efficient functioning of any business organization would enable it to provide goods/services at a lower price.

In the process of managing organizations, the managers at different levels should take appropriate economic decisions which will help in minimizing investment, operating and maintenance expenditures besides increasing the revenue, savings and such other gains of the organization.

These can be achieved through Engineering Economics which deals with the methods that enable one to make economic decisions towards minimizing costs and/or maximizing benefits to business organizations.

This chapter discusses the elements of economics and the interaction between its various components.

This is followed by an analysis of the need and scope of engineering economics. Later, elements of cost and break-even analysis are presented.

1.2 Economics - is a study of economic problems of the people concerning production, consumption, exchange and distribution of wealth.

Economics is the science that deals with the production and consumption of goods and services and the distribution and rendering of these for human welfare.

The following are the economic goals.

- ✓ A high level of employment
- ✓ Price stability
- ✓ Efficiency
- ✓ An equitable distribution of income
- ✓ Growth

1.3 Flow in economy The flow of goods, services, resources and money payments in a simple economy

Households and businesses are the two major entities in a simple economy.

- ✓ Business organizations use various economic resources like land, labour and capital which are provided by households to produce consumer goods and services which will be used by them.

- ✓ Business organizations make payment of money to the households for receiving various resources.
- ✓ The households in turn make payment of money to business organizations for receiving consumer goods and services.
- ✓ This cycle shows the interdependence between the two major entities in a simple economy.

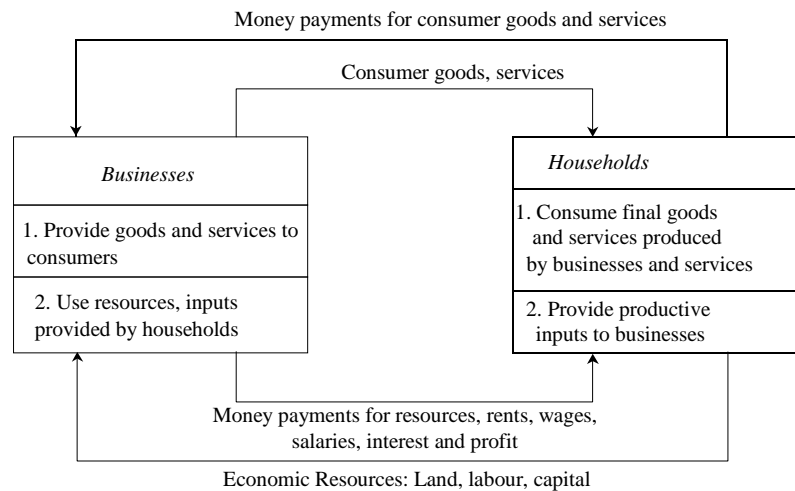


Fig. Flow of goods, services, resources and money payments in a simple economy.

1.4 Laws of supply and demand

1.3.1 Laws of supply - states that the quantity of a commodity supplied varies directly with the price, other determinants of supply remaining constant.

- ✓ If the cost of inputs increases, then naturally, the cost of the product will go up. In such a situation, at the prevailing price of the product the profit margin per unit will be less.
- ✓ The producers will then reduce the production quantity, which in turn will affect the supply of the product.
- ✓ For instance, if the prices of fertilizers and cost of labour are increased significantly, in agriculture, the profit margin per bag of paddy will be reduced.
- ✓ So, the farmers will reduce the area of cultivation, and hence the quantity of supply of paddy will be reduced at the prevailing prices of the paddy.
- ✓ If there is an advancement in technology used in the manufacture of the product in the long run, there will be a reduction in the production cost per unit.
- ✓ This will enable the manufacturer to have a greater profit margin per unit at the prevailing price of the product. Hence, the producer will be tempted to supply more quantity to the market.
- ✓ Weather also has a direct bearing on the supply of products. For example, demand for woollen products will increase during winter. This means the prices of woollen

- goods will be increased in winter.
- ✓ So, naturally, manufacturers will supply more volume of woollen goods during winter.

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Factors influencing supply

The shape of the supply curve is affected by the following factors:

- ✓ Cost of the inputs
- ✓ Technology
- ✓ Weather
- ✓ Prices of related goods

1.3.2 Law of demand states that other things being equal demand when price falls and contracts when price rises.

- **Market demand** is the total quantity demanded by all the purchasers together.
- **Elasticity of Demand** - Elasticity of demand may be defined as the degree of responsiveness of quantity demanded to a change in price.
- ✓ An interesting aspect of the economy is that the demand and supply of a product are interdependent and they are sensitive with respect to the price of that product..
- ✓ From Fig. it is clear that when there is a decrease in the price of a product, the demand for the product increases and its supply decreases.
- ✓ Also, the product is more in demand and hence the demand of the product increases.
- ✓ At the same time, lowering of the price of the product makes the producers restrain from releasing more quantities of the product in the market.
- ✓ Hence, the supply of the product is decreased. The point of intersection of the supply curve and the demand curve is known as the equilibrium point.
- ✓ At the price corresponding to this point, the quantity of supply is equal to the quantity of demand. Hence, this point is called the equilibrium point.

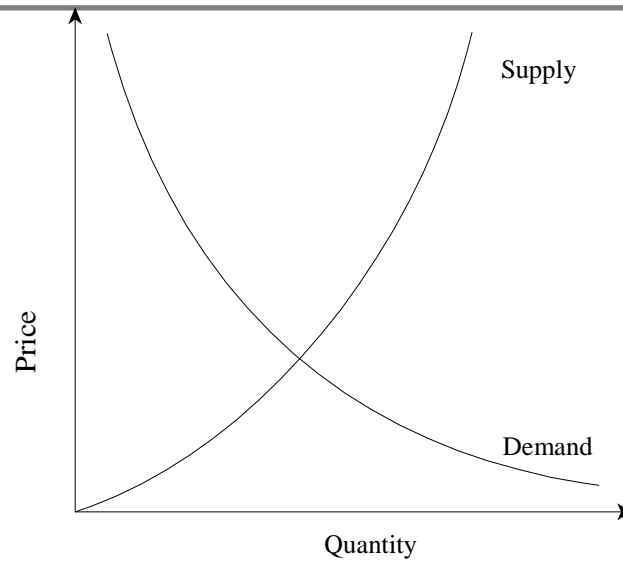


Fig. Demand and supply curve.

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Factors influencing demand

The shape of the demand curve is influenced by the following factors:

- ✓ From the discussions in the previous section, it is clear that price has a major role in deciding the demand and supply of a product.
- ✓ Hence, from the organization's point of view, efficient and effective functioning of the organization would certainly help it to provide goods/services at a lower cost which in turn will enable it to fix a lower price for its goods or services.
- ✓ The following section discusses the different types of efficiency and their impact on the operation of businesses and the definition and scope of engineering economics.

1.5 Types of Efficiency

Efficiency of a system is generally defined as the ratio of its output to input. The efficiency can be classified into technical efficiency and economic efficiency.

1. Technical efficiency

- ✓ Income of the people
- ✓ Prices of related goods
- ✓ Tastes of consumers

1.5 Concept of Engineering Economics

- ✓ Science is a field of study where the basic principles of different physical systems are formulated and tested.
- ✓ Engineering is the application of science. It establishes varied application systems based on different scientific principles.

It is the ratio of the output to input of a physical system. The physical system may be a diesel engine, a machine working in a shop floor, a furnace, etc.

$$\text{Technical efficiency (\%)} = \frac{\text{Output}}{\text{Input}} \times 100$$

The technical efficiency of a diesel engine is as follows:

$$\text{Technical efficiency (\%)} = \frac{\text{Heat equivalent of mechanical energy produced}}{\text{Heat equivalent of fuel used}} \times 100$$

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In practice, technical efficiency can never be more than 100%.

This is mainly due to frictional loss and incomplete combustion of fuel, which are considered to be unavoidable phenomena in the working of a diesel engine.

1. Economic efficiency

Economic efficiency is the ratio of output to input of a business system.

$$\text{Economic efficiency (\%)} = \frac{\text{Output}}{\text{Input}} \times 100 = \frac{\text{Worth}}{\text{Cost}} \times 100$$

‘Worth’ is the annual revenue generated by way of operating the business and ‘cost’ is the total annual expenses incurred in carrying out the business. For the survival and growth of any business, the economic efficiency should be more than 100%.

Economic efficiency is also called ‘productivity’. There are several ways of improving productivity.

- Increased output for the same input
- Decreased input for the same output
- By a proportionate increase in the output which is more than the proportionate increase in the input

- By a proportionate decrease in the input which is more than the proportionate decrease in the output
- Through simultaneous increase in the output with decrease in the input.

1.6 Definition and Scope of Engineering Economics

As stated earlier, efficient functioning of any business organization would enable it to provide goods/services at a lower price.

In the process of managing organizations, the managers at different levels should take appropriate economic decisions which will help in minimizing investment, operating and maintenance expenditures besides increasing the revenue, savings and other related gains of the organization.

1.6.1 Definition

Engineering economics deals with the methods that enable one to take economic decisions towards minimizing costs and/or maximizing benefits to business organizations.

1.6.2 Scope

The issues that are covered in this book are elementary economic analysis, interest formulae, bases for comparing alternatives, present worth method, future worth method, annual equivalent method, rate of return method, replacement analysis, depreciation, evaluation of public alternatives, inflation adjusted investment decisions, make or buy decisions, inventory control, project management, value engineering, and linear programming.

1.7 Elements of Costs

Cost can be broadly classified into *variable cost* and *overhead cost*. Variable cost varies with the volume of production while overhead cost is fixed, irrespective of the production volume.

Variable cost can be further classified into direct material cost, direct labour cost, and direct expenses. The overhead cost can be classified into factory overhead, administration overhead, selling overhead, and distribution overhead.

Direct material costs are those costs of materials that are used to produce the product. Direct labour cost is the amount of wages paid to the direct labour involved in the production activities.

Direct expenses are those expenses that vary in relation to the production volume, other than the direct material costs and direct labour costs.

Overhead cost is the aggregate of indirect material costs, indirect labour costs and indirect expenses. Administration overhead includes all the costs that are incurred in administering the business.

Selling overhead is the total expense that is incurred in the promotional activities and the expenses relating to sales force. Distribution overhead is the total cost of shipping the items from the factory site to the customer sites.

The selling price of a product is derived as shown below:

- (a) Direct material costs + Direct labour costs + Direct expenses = Primecost
- (b) Prime cost + Factory overhead = Factory cost
- (c) Factory cost + Office and administrative overhead = Costs of production
- (d) Cost of production + Opening finished stock – Closing finished stock = Cost of goods sold
- (e) Cost of goods sold + Selling and distribution overhead = Cost of sales
- (f) Cost of sales + Profit = Sales
- (g) Sales/Quantity sold = Selling price per unit

In the above calculations, if the opening finished stock is equal to the closing finished stock, then the cost of production is equal to the cost of goods sold.

1.8 Other Costs/Revenues

The following are the costs/revenues other than the costs which are presented in the previous section:

- ✓ Marginalcost
- ✓ Marginalrevenue
- ✓ Sunkcost
- ✓ Opportunitycost

1. Marginal Cost

Marginal cost of a product is the cost of producing an additional unit of that product. Let the cost of producing 20 units of a product be Rs. 10,000, and the cost of producing 21 units of the same product be Rs. 10,045. Then the marginal cost of producing the 21st unit is Rs.45.

2. Marginal Revenue

Marginal revenue of a product is the incremental revenue of selling an additional unit of that product. Let, the revenue of selling 20 units of a product be Rs. 15,000 and the revenue of selling 21 units of the same product be Rs. 15,085. Then, the marginal revenue of selling the 21st unit is Rs.85.

3. Sunk Cost

This is known as the past cost of an equipment/asset. Let us assume that an equipment has been purchased for Rs. 1,00,000 about three years back. If it is considered for replacement, then its present value is not Rs. 1,00,000. Instead, its present market value should be taken as the present value of the equipment for further analysis.

So, the purchase value of the equipment in the past is known as its sunk cost. The sunk cost should not be considered for any analysis done from now onwards.

4. Opportunity Cost

In practice, if an alternative (X) is selected from a set of competing alternatives (X, Y), then the corresponding investment in the selected alternative is not available for any other purpose. If the same money is invested in some other alternative (Y), it may fetch some return. Since the money is invested in the selected alternative (X), one has to forego the return from the other alternative (Y).

The amount that is foregone by not investing in the other alternative (Y) is known as the opportunity cost of the selected alternative (X). So the opportunity cost of an alternative is the return that will be foregone by not investing the same money in another alternative.

1.9 Break-Even Analysis

The main objective of break-even analysis is to find the cut-off production volume from where a firm will make profit.

Let

s = selling price per unit
v = variable cost per unit
FC = fixed cost per period
Q = volume of production

The total sales revenue (S) of the firm is given by the following formula:

$$S = s \cdot Q$$

The total cost of the firm for a given production volume is given as

$$\begin{aligned} TC &= \text{Total variable cost} + \text{Fixed cost} \\ &= vQ + FC \end{aligned}$$

- The linear plots of the above two equations are shown in Fig..
 - The intersection point of the total sales revenue line and the total cost line is called the break-even point.
 - The corresponding volume of production on the X-axis is known as the break-even sales quantity.
 - At the intersection point, the total cost is equal to the total revenue. This point is also called the no-loss or no-gainsituation.
 - For any production quantity which is less than the break-even quantity, the total cost is more than the total revenue.
- Hence, the firm will be making loss.

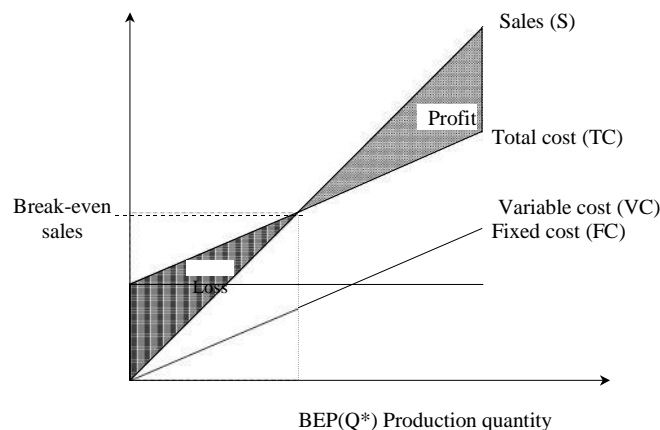


Fig. Break-even chart.

For any production quantity which is more than the break-even quantity, the total revenue will be more than the total cost. Hence, the firm will be making profit.

$$\text{Profit} = \text{Sales} - (\text{Fixed cost} + \text{Variable costs})$$

$$= sQ - (FC + vQ)$$

The formulae to find the break-even quantity and break-even sales quantity

$$\text{Break-even quantity} = \frac{\text{Fixed cost}}{\text{Selling price/unit} - \text{Variable cost/unit}}$$

$$= \frac{FC}{s - v} \text{ (in units)}$$

$$\text{Break-even sales} = \frac{\text{Fixed cost}}{\text{Selling price/unit} - \text{Variable cost/unit}} \times \text{Selling price/unit}$$

$$= \frac{FC}{s - v} \times s \text{ (Rs.)}$$

The contribution is the difference between the sales and the variable costs. The margin of safety (M.S.) is the sales over and above the break-even sales. The formulae to compute these values are

$$\text{Contribution} = \text{Sales} - \text{Variable costs}$$

$$\text{Contribution/unit} = \text{Selling price/unit} - \text{Variable cost/unit}$$

$$\text{M.S.} = \text{Actual sales} - \text{Break-even sales}$$

$$= \frac{\text{Profit}}{\text{Contribution}} \times \text{sales}$$

$$\text{M.S. as a percent of sales} = \left(\frac{\text{M.S.}}{\text{Sales}} \right) \times 100$$

1.10 Profit/Volume Ratio (P/VRatio)

P/V ratio is a valid ratio which is useful for further analysis.

The different formulae for the *P/V* ratio are as follows:

$$P/V \text{ ratio} = \frac{\text{Contribution}}{\text{Sales}} = \frac{\text{Sales} - \text{Variable costs}}{\text{Sales}}$$

The relationship between BEP and *P/V* ratio is as follows:

$$\text{BEP} = \frac{\text{Fixedcost}}{P/V\text{ratio}}$$

1.11 Elementary Economic Analysis

Whether it is a business situation or a day-to-day event in somebody's personal life, there are a large number of economic decision making involved. One can manage many of these decision problems by using simple economic analysis.

For example, an industry can source its raw materials from a nearby place or from a far-off place. In this problem, the following factors will affect the decision:

- ✓ Price of the rawmaterial
- ✓ Transportationcostoftherawmaterial
- ✓ `Availability of the rawmaterial
- ✓ Quality of the rawmaterial

Consider the alternative of sourcing raw materials from a nearby place with the following characteristics:

- ✓ The raw material is more costly in the nearbyarea.
- ✓ The availability of the raw material is not sufficient enough to support the operation of the industry throughout theyear.
- ✓ The raw material requires pre-processing before it is used in the production process. This would certainly add cost to the product.
- ✓ Thecostoftransportationisminimalunderthisalternative.

On the other hand, consider another alternativeof sourcing the rawmaterialsfromafar-offplacewiththefollowingcharacteristics:

- ✓ Therawmaterialislesscostlyatthefaroffplace.
- ✓ The cost of transportation is veryhigh.
- ✓ The availability of the raw material at this site is abundant and it can support the plant throughoutthe year.

The raw material from this site does not require any pre- processing before using it for production.

1.12 Material Selection For A Product/Substitution OfRaw Material

The cost of a product can be reduced greatly by substitution of the raw materials.

Among various elements of cost, raw material cost is most significant and it forms amajorportionofthetotalcostofanyproduct.

So, any attempt to find a suitable raw material will bring a reduction in the total cost in any one or combinations of the followingways:

- ✓ Reduced machining/processtime

- ✓ Enhanced durability of the product
- ✓ Cheaper raw material price

Therefore, the process of raw material selection/substitution will result in finding an alternate raw material which will provide the necessary functions that are provided by the raw material that is presently used.

In this process, if the new raw material provides any additional benefit, then it should be treated as its welcoming feature. This concept is demonstrated with numerical problem given below

Example

In the design of a jet engine part, the designer has a choice of specifying either an aluminium alloy casting or a steel casting. Either material will provide equal service, but the aluminium casting will weigh 1.2 kg as compared with 1.35 kg for the steel casting.

The aluminium can be cast for Rs. 80.00 per kg. and the steel one for Rs. 35.00 per kg. The cost of machining per unit is Rs. 150.00 for aluminium and Rs. 170.00 for steel. Every kilogram of excess weight is associated with a penalty of Rs. 1,300 due to increased fuel consumption. Which material should be specified and what is the economic advantage of the selection per unit?

Solution (a) Cost of using aluminium metal for the jet engine part:

$$\begin{aligned} \text{Weight of aluminium casting/unit} &= 1.2 \text{ kg} \\ \text{Cost of making aluminium casting} &= \text{Rs. } 80.00 \text{ per kg} \\ \text{Cost of machining aluminium casting per unit} &= \text{Rs. } 150.00 \\ \text{Total cost of jet engine part made of aluminium/unit} \\ &= \text{Cost of making aluminium casting/unit} \\ &\quad + \text{Cost of machining aluminium} \\ &\quad \quad \text{casting/unit} \\ &= 80 \times 1.2 + 150 = 96 + 150 \\ &= \text{Rs. } 246 \end{aligned}$$

(b) Cost of jet engine part made of steel/unit:
Weight of steel casting/unit = 1.35 kg
Cost of making steel casting = Rs. 35.00 per kg
Cost of machining steel casting per unit = Rs. 170.00
Penalty of excess weight of steel casting = Rs. 1,300per kg

Total cost of jet engine part made of steel/unit
= Cost of making steel casting/unit
+ Cost of machining steel
casting/unit
+ Penalty for excess weight of steel
casting
=35 1.35+170+1,300(1.35–1.2)
= Rs. 412.25

DECISION The total cost/unit of a jet engine part made of aluminium is less than that for an engine made of steel. Hence, aluminium is suggested for making the jet engine part. The economic advantage of using aluminium over steel/unit is Rs. 412.25 – Rs. 246 = Rs. 166.25

1.12.1 Design Selection for aProduct

- a. The design modification of a product may result in reduced raw material requirements, increased machinability of the materials and reduced labour.
- b. Design is an important factor which decides the cost of the product for a specifiedlevelofperformanceofthatproduct.

Example

(Design selection for a process industry). The chief engineer of refinery operations is not satisfied with the preliminary design for storage tanks to be used as part of a plant expansion programme. The engineer who submittedthe design was called in and asked to reconsider the overall dimensions in the light of an article in the *Chemical Engineer*, entitled “How to size future processvessels?”

The original design submitted called for 4 tanks 5.2 m in diameter and 7 m in height. From a graph of the article, the engineer found that the present ratio of height to diameter of 1.35 is 111% of the minimum cost and that the minimum cost for a tank was when the ratio of height to diameter was 4 : 1. The cost for the tank design as originally submitted was estimated to be Rs. 9,00,000. What are the optimum tank dimensions if the volume remains the same as for the original design? What total savings may be expected through theredesign?

Solution

(a) *Original design*

Number of tanks = 4

Diameter of the tank = 5.2 m

Radius of the tank = 2.6 m

Height of the tank = 7 m

Ratio of height to diameter = $7/5.2 = 1.35$

$$\begin{aligned}\text{Volume/tank} &= \frac{22}{7} r^2 h = \frac{22}{7} (2.6)^2 \cdot 7 \\ &= 148.72 \text{ m}^3\end{aligned}$$

(b) *New design*

Cost of the old design = 111% of the cost of the new design (optimal design)

Optimal ratio of the height to diameter = 4:1

$$\begin{aligned}\text{Cost of the new design} &= 9,00,000 \quad (100/111) \\ &= \text{Rs. } 8,10,810.81\end{aligned}$$

$$\begin{aligned}\text{Expected savings by the redesign} &= \text{Rs. } 9,00,000 - \text{Rs. } 8,10,810.81 \\ &= \text{Rs. } 89,189.19\end{aligned}$$

1.13 Process Planning /ProcessModification

While planning for a new component, a feasible sequence of operations with the least cost of processing is to be considered.

The process sequence of a component which has been planned in the past is notstatic.

It is always subject to modification with a view to minimize the cost of manufacturing the component.

So, the objective of process planning/process modification is to identify the most economical sequence of operations to produce a component.

The steps in process planning are as follows:

1. Analyze the part drawing to get an overall picture of what is required.
2. Make recommendations to or consult with product engineers on product designchanges.
3. List the basic operations required to produce the part to the drawing orspecifications.
4. Determine the most practical and economical manufacturing method and the form or tooling required for eachoperation.
5. Devise the best way tocombine the operations and put them insequence.
6. Specify the gauging required for theprocess.

Steps 3–5 aim to determine the most practical and economical sequence of operations to produce a component. This concept is demonstrated with a numerical problem.

Example

The process planning engineer of a firm listed the sequences of operations as shown in Table to produce a component.

Table Data for Example

<i>Sequence</i>	
<i>Process sequence</i>	
1	Turning – Milling – Shaping –Drilling
2	Turning – Milling –Drilling
3	<u>All operations are performed with CNC machine</u>

The details of processing times of the component for various operations and their machine hour rates are summarized in Table below

Machine Hour Rates and Processing Times (minutes) for Example

Operation	Machine hour sequence rate (Rs.)	Process		
		1	2	3
Turning	200		5	5
– Milling	400		8	14
– Shaping	350		10	–
– Drilling	300		3	3
– CNC operations	1,000	–	–	8

Find the most economical sequence of operations to manufacture the component.

Solution (a) *Cost of component using process sequence 1.* The process sequence 1 of the component is as follows:

Turning – Milling – Shaping – Drilling

The calculations for the cost of the above process sequence are summarized in Table.

Table WorkingsforProcessSequence1

Operation No.	Operation	Time		Machine hour rate (Rs.)	Cost (Rs.)
		(min)	(hr)		
1	Turning	5	0.083	200	16.60
2	Milling	8	0.133	400	53.20
3	Shaping	10	0.167	350	58.45
4	Drilling	3	0.050	300	15.00
Total:					143.25

(b) *Cost of component using process sequence 2.* The process sequence 2 of the component is as follows:

Turning – Milling – Drilling

The calculations for the cost of the above process sequence are given in Table

Table WorkingsforProcessSequence2

Operation No.	Operation	Time		Machine hour rate (Rs.)	Cost (Rs.)
		(min)	(hr)		
1	Turning	5	0.083	200	16.60
2	Milling	14	0.233	400	93.20
3	Drilling	3	0.050	300	15.00
Total:					124.80

(c) *Cost of component using process sequence 3.* The process sequence 3 of the component is as follows:

Only CNC operations

The calculations for the cost of the above process sequence are summarized in Table

Table WorkingsforProcessSequence3

<i>Operation No.</i>	<i>Operation</i>	<i>Time</i>		<i>Machine hourrate (Rs.)</i>	<i>Cost (Rs.)</i>
		<i>(min)</i>	<i>(hr)</i>		
1	CNC operations	8	0.133	1,000	133

The process sequence 2 has the least cost. Therefore, it should be selected for manufacturing the component.