NEXT IAS

BIG LEARNINGS MADE EASY

# Manufacturing Management

## Mechanical Engineering

Comprehensive Theory *with* Solved Examples

## Civil Services Examination

**MADE EASY Publications Pvt. Ltd.**

Corporate Office: 44-A/4, Kalu Sarai (Near Hauz Khas Metro Station), New Delhi-110016
E-mail: infomep@madeeasy.in
Contact: 9021300500
Visit us at: www.madeeasypublications.org

**Manufacturing Management**



First Edition : 2018
Second Edition : 2019
Reprint : 2020
Reprint : 2021
Reprint : 2022
Reprint : 2023

**Reprint : 2024**

# Contents

# Manufacturing Management

## Chapter 5



## Chapter 6



## Chapter 7



## Chapter 8



## Chapter 9



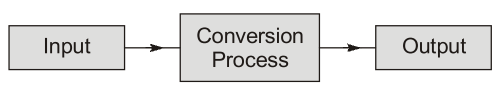
## Chapter 10

Chapter 01

# Break Even Analysis

## 1.1 Production

It is the step by step value addition process of converting one form of material into another form to increase the utility of the product for the user.




## 1.2 Production System

It is an organised process of converting raw material into final product with a feedback loop.

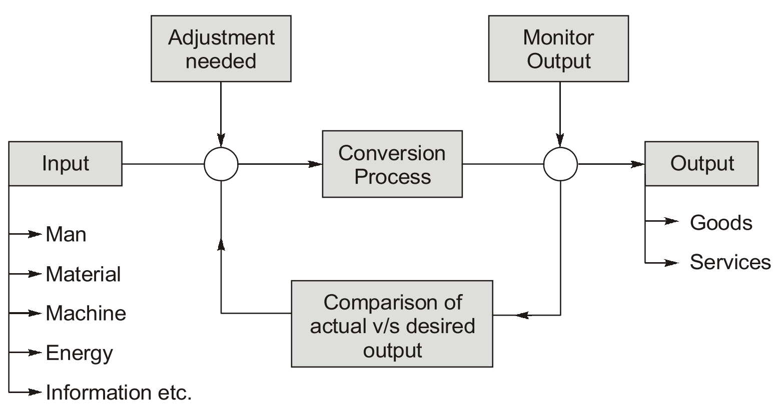



**Fig.**

## 1.3 Productivity

$$\text{Productivity} = \frac{\text{Output}}{\text{Input}}$$

It is quantitative ratio between what we produce and what we use as a resources to produce them. Every organisation always want to increases the productivity by applying new techniques and method.

## 1.4 Cost in Production

(i) Prime or direct cost:

Direct cost = Direct material + Direct labour + Direct expenses

(ii) Factory overhead or factory expenses

Factory overhead = Indirect Material + Indirect Labour + Indirect Expenses

- Indirect Material → Not part of final Material. Ex.: Cutting fluids, Lubricants, Cotton, Jute, Stationary items.
- Indirect Labour → Ex. Watchman, Supervisor, Higher officers
- Indirect Expenses → Rent of building, telephone bills, facility development and electricity bills

(iii) Factory cost

Factory cost = Prime cost + Factory overhead

Final cost of product just at the outlet of factory.

(iv) Total cost

Total cost = Factory cost + Marketing, Advertising, Transportation cost etc.

(v) Selling cost

Selling cost = Total cost + Profit

## 1.5 Break Even Analysis (BEA)

BEA deals with (i) Total cost
(ii) Selling cost
(iii) Volume of production

### Total Cost

It indicates the total expenditure made in order to produce certain number of units and it is the sum of fixed and variable cost.

(a) Fixed Cost

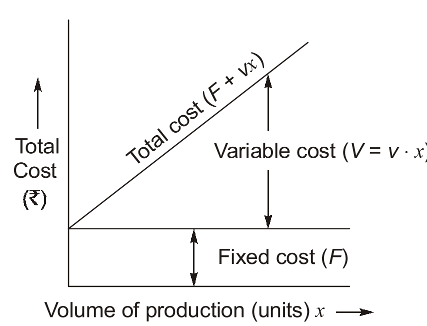



**Fig.**

This cost remain fixed or constant irrespective of the volume of production. It includes cost of the machine, rent of building, salary of watchman, higher officers, advertisement cost, insurance cost, interest etc.

(b) Variable Cost ($V = v \cdot x$)

This cost increases directly and proportionally with the volume of production and it includes direct material, direct labour and running cost.

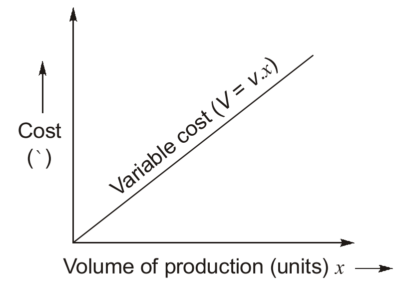



**Fig.**

Notations:

$F$ = Fixed cost in rupees.

$x$ = Number of units produced in order to earn profit 'P'.

$v$ = Variable cost/unit (₹/unit)

$V$ = Total variable cost in ₹ ($v \times x$)

$s$ = Selling price/unit (₹/unit)

$S$ = Total sale or revenue in ₹ ($s \times x$)

**NOTE :** Break even point is least affected by "volume of production". It depends on total cost, selling cost and variable cost.

## 1.6 Total Sale or Revenue

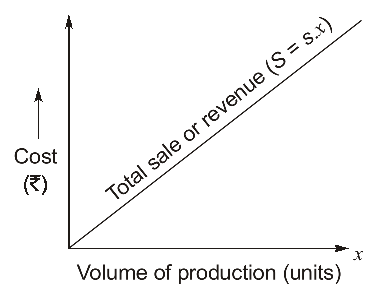



**Fig.**

It is directly proportional to the volume of production. Total sale indicates the return obtained by selling out the quantity to be produced.

## 1.7 Break Even Chart

Brake even point is the volume of production where total sales is equal to total cost and organisation neither earns profit nor suffer loss. It is also known as no profit and no loss point.

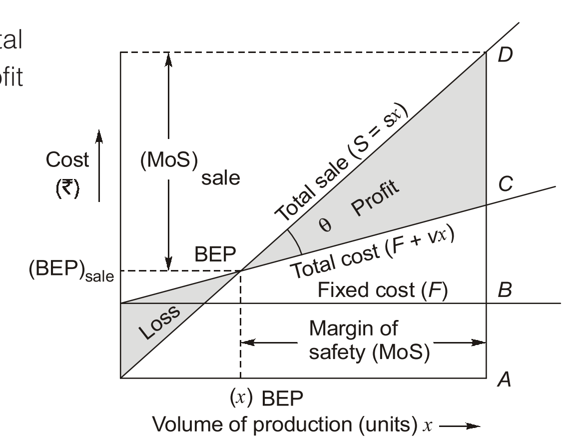



**Fig.**

$$\text{Total sale} = \text{Total cost} + \text{profit}$$

$$\text{Total sale} = S = sx$$

$$\text{Total cost} = F + V = F + vx$$

$$\text{Profit} = P$$

$$S = F + vx + P$$

or

$$s.x = F + vx + P$$

$$(s - v)x = F + P$$

$$x = \frac{F + P}{(s - v)}$$

Number of volume produced for profit '$P$'.

$$x = \frac{F + P}{(s - v)}$$

At BEP, Profit, $P = 0$

$$x_{BEP} = \frac{F}{(s-v)} \text{units}$$

$$(BEP)_{sale} = x_{BEP} \cdot s = \frac{F}{(s-v)} \cdot s$$

## 1.8 Angle of Incidence (θ)

It is angle at which total sales line cut the total cost line. Larger this angle better will be the working conditions.

## 1.9 Contribution Margin

$$\text{C.M.} = \text{Total sale} - \text{Total variable cost}$$

$$\text{C.M.} = S - V = (s - v) \cdot x$$

$$\text{Contribution} = (s - v)$$

*Contribution of producing one more unit in our profit* $= (s - v)$

Also, $S = F + V + P$

$$S - V = F + P = CM$$

$$CM = F + P = (s - v)x$$

Also known as marginal profit or gross margin.

## 1.10 Profit Volume Graph

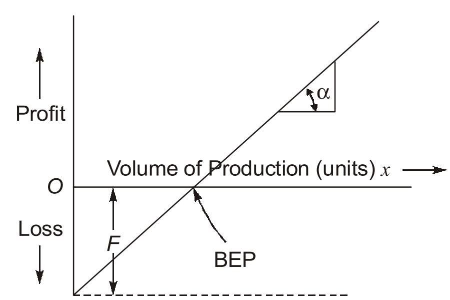



**Fig.**

$$sx = F + vx + P$$

$$P = sx - vx - F = (s - v)\,x - F$$

At $x = 0$ loss will be maximum i.e., equal to fixed cost.

## 1.11 Profit Volume Ratio

**($P/V$) ratio:** It is the terms used to represent profitability related to sales. This ratio always remains constant for a particular product and it is ratio of contribution margin to the volume of sales.

$$(P/V)_{ratio} = \frac{CM}{S}$$

$$(P/V)_{ratio} = \frac{CM}{S} = \frac{(s-v)}{s} = \frac{F+P}{S}$$

$$\frac{F+P_1}{S_1} = \frac{F+P_2}{S_2}$$

**NOTE :** $(P/V)_{\text{ratio}}$ for any product always remains constant.

For increasing the sales $\rightarrow$ Heighest $(P/V)_{\text{ratio}}$ should be preferred.

For decreasing the sales $\rightarrow$ Lowest $(P/V)_{\text{ratio}}$ should be preferred.

If we want to increases the sales by 1 lakh rupees, then profit will increases maximum for the product which is having heighest $(P/V)_{\text{ratio}}$.

$$(P/V)_{\text{ratio}} = \frac{\Delta P}{\Delta S}$$

## 1.12 Margin of Safety (MoS)

It is the difference of output at full capacity compare to output at break even point.

$$(\text{MoS})_{\text{sales}} = (\text{Sale})_x - (\text{Sale})_{\text{BEP}}$$

$$(\text{MoS})_{\text{sales}} = S_x - S_{\text{BEP}}$$

$$\text{MoS\%} = \left(\frac{S_x - S_{\text{BEP}}}{S_x}\right) \times 100$$

**Remember**

1. *No. of volume produced for profit 'P',* $x = \dfrac{F+P}{(s-v)}$
2. $x_{\text{BEP}} = \dfrac{F}{(s-v)}$ units
3. $(\text{BEP})_{\text{sale}} = x_{\text{BEP}} \cdot s = \dfrac{F}{(s-v)} \cdot s$

**Example 1.1** A product can be produced by 4 process as given below in order to produce 100 units which process should be preferred:

| Process | $F$(₹) | $v$ (₹/unit) |
|---|---|---|
| I | 20 | 3 |
| II | 30 | 2 |
| III | 10 | 4 |
| IV | 40 | 1 |

**Solution:**

We know that,

$$TC = F + vx$$

If $$x = 100$$

(i) $20 + (3 \times 100) = 320$

(ii) $30 + (2 \times 100) = 230$

(iii) $10 + (4 \times 100) = 410$

(iv) $40 + (1 \times 100) = 140$

So, $TC$ is minimum for process (iv). So we will prefer process (iv).

**Example 1.2** A company requires a product for which they have 3 options

(i) Purchase @ 10/unit

(ii) Produce by semi-automatic machine; $F$ = ₹ 3400, $v$ = ₹ 6/unit

(iii) Produce by fully automatic machine; $F$ = ₹ 20,200 $v$ = ₹ 3/unit

Find the decision rule.

**Solution:**

(i) Total cost $= 10 \times x$

(ii) Total cost $= 3400 + 6x$

(iii) Total cost $= 20{,}200 + 3x$

Taking (i) and (ii) and equating their total cost

$$\Rightarrow \quad 10x = 3400 + 6x$$

$$4x = 3400$$

$x$ = 850, means after 850 units process (ii) will be more profitable.

Taking (ii) and (iii) and equating their total cost

$$3400 + 6x = 20{,}200 + 3x; \quad 6x = 16800$$

$x = \dfrac{16800}{3} = 5600$ , means after 5600 units process (iii) will be more profitable.

At $x_1$, $(T.C.)_{I} = (T.C.)_{II}$

$$10x = 3400 + 6x$$

$$4x = 3400$$

$$x = 850 \rightarrow x_1$$

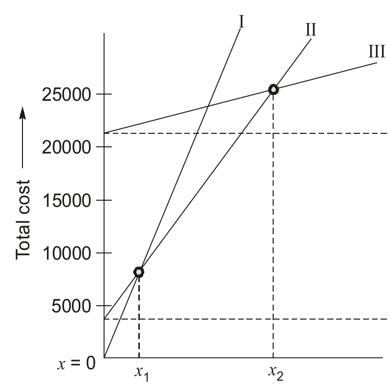
At $x_2$, $3400 + 6x = 20{,}200 + 3x$

$$x = 5600 \rightarrow x_2$$

$0 < x \le 850$ = I[st] option

$850 \le x \le 5600$ = II[nd] option

$5600 \le x$ = III[rd] option




**Example 1.3** In a production system fixed cost of ₹ 9000. Total variable cost ($v$) = ₹ 15000. Total sales ($F + V + P$) = ₹ 30,000 and number of unit produce ($x$) = 5000. Then determine

(i) $(BEP)_{unit}$ (ii) (MoS) (iii) Quantity to be produced for profit of ₹ 30000.

**Solution:**

$F$ = ₹ 9000; $V = vx$ = ₹ 15000; $x = 5000$; $v$ = ₹ 3; $F + V + P$ = ₹ 30,000

$P$ = 30000 – 15000 – 9000 = ₹ 6000

(i) $$x_{BEP} = \frac{F}{s - v} = \frac{9000}{6-3} = \frac{9000}{3} = 3000 \text{ units}$$

(ii) $(MoS) = (Sales)_x - (Sales)_{BEP}$

= 30,000 – 18000 = ₹ 12000

[$\because$ $(Sales)_{BEP} = x_{BEP} \times s$ = ₹ 18000]

(MoS)% = 40%

(iii) $$x = \frac{F + P}{s - v} = \frac{9000 + 30000}{6 - 3} = 13000 \text{ units}$$

**Example 1.4** Following data is given for producing toys at two different plants:

| Cost | Plant 1 | Plant 2 |
|---|---|---|
| Fixe cost, ₹ | 250000 | 120000 |
| Direct material cost (₹/unit) | 13.5 | 17.0 |
| Direct labour cost (₹/unit) | 8.2 | 8.5 |
| Variable overhead (₹/unit) | 2.1 | 2.3 |

Find the break even quantity between these locations.

**Solution:**

At break even quantity, total cost for both the plants for same quantity should be same.

Assuming total number of units at breakeven is '$q$'.

$$(TC)_1 = (TC)_2$$

$$\Rightarrow \quad 250000 + q[13.5 + 8.2 + 2.1] = 120000 + q[17 + 8.5 + 2.3]$$

$$\Rightarrow \quad 250000 - 120000 = q[27.8 - 23.8]$$

$$\Rightarrow \quad q = \frac{250000 - 120000}{4} = 32500 \text{ units}$$

∴ Number of quantity produced at breakeven between these locations = 32500 units

**Example 1.5** A plant is manufacturing 3750 heavy duty lathes per year is operating at 75% of its capacity. The annual sales return is ₹1,68,75,000. The fixed cost of the plant is ₹50,00,000 and the variable cost is ₹3875 per unit. There is a proposal to utilize spare capacity by manufacturing precision lathes which could increase the fixed cost by ₹1800000 but reduce the variable cost by ₹775 per unit.

(a) Is the proposal economical? Give reason for your answer.

(b) If a increase in selling price by ₹250 per unit requires the plant to be run at 60% of its capacity to break-even, would this be a better proposal than the earlier one?

**Solution:**

Present sales capacity, $n = 3750$ units

$$\text{Plant capacity, } N = \frac{3750}{0.75} = 5000 \text{ units}$$

$$\text{Profit} = [(s - v) \times n - F]$$

$$= [16875000 - (3875 \times 3750) - 5000000] = -₹\ 2656250$$

∴ Loss of ₹2656250

(a) Using full plant capacity:

$$\text{Profit} = \left[\frac{16875000}{3750} \times 5000 - 3100 \times 5000\right] - 6800000$$

$$= ₹200000$$

Yes, it is advisable to use full capacity because there is a net profit of ₹200000.

(b) $$\text{BEP} = \frac{F}{s - v} = \frac{5000000}{\left(\frac{16875000}{3750} - 3875\right)} = 8000$$

$$\text{Profit} = [(s - v) \times n - F]$$

$$= \left[\left\{\left(\frac{16875000}{3750} + 250\right) - 3875\right\} \times 0.6 \times 8000 - 5000000\right]$$

$$= ₹\,(-800000)$$

This plan is better than original one but not better than the earlier plan because there is a net loss of ₹800000.

**Example 1.6** Three firms *A*, *B* and *C* manufacture the same product. The selling price is ₹10 per unit of the product which is same for all firms. The fixed cost for firms *A*, *B* and *C* are ₹100000, ₹200000 and ₹324000 respectively; while the variable costs are ₹8, ₹5 and ₹4 respectively. Determine the breakeven points for all the firms. How much profits are earned by the firms if each of them sell 80000 units? What will be the impact on their profits if sales

(a) Increases by 25%

(b) Decreases by 25%

**Solution:**

Break even point for the firms are:

Firm *A*, $$\text{BEP} = \frac{F}{s - v} = \frac{100000}{10 - 8} = 50000 \text{ units}$$

Firm *B*, $$\text{BEP} = \frac{F}{s - v} = \frac{200000}{10 - 5} = 40000 \text{ units}$$

Firm *C*, $$\text{BEP} = \frac{F}{s - v} = \frac{324000}{10 - 4} = 54000 \text{ units}$$

Profits made by three firms at a sale of 80000 units are:

Firm *A*, $$\text{Profit} = [(s - v)n - F] = [(10 - 8) \times 80000 - 100000] = ₹60000$$

Firm *B*, $$\text{Profit} = [(s - v)n - F] = [(10 - 5) \times 80000 - 200000] = ₹200000$$

Firm *C*, $$\text{Profit} = [(s - v)n - F] = [(10 - 4) \times 80000 - 324000] = ₹156000$$

Profit when sales increases by 25%:

Firm *A*, $$\text{Profit} = [(10 - 8) \times 80000 \times 1.25 - 100000] = ₹100000$$

$$\%\text{ increase in profit} = \frac{100000 - 60000}{60000} \times 100\% = 66.67\%$$

Firm *B*, $$\text{Profit} = [(10 - 5) \times 80000 \times 1.25 - 200000] = ₹300000$$

$$\%\text{ increase in profit} = \frac{300000 - 200000}{200000} \times 100\% = 50\%$$

Firm *C*, $$\text{Profit} = [(10 - 4) \times 80000 \times 1.25 - 324000] = ₹276000$$

$$\% \text{ increase in profit} = \frac{276000 - 156000}{156000} \times 100\% = 76.923\%$$

Effect on profit when sales decreases by 25%:

Firm *A*, Profit $= [(10 - 8) \times 80000 \times 0.75 - 100000]$
$= ₹20000$

$$\% \text{ decrease in profit} = \frac{60000 - 20000}{60000} \times 100\% = 66.67\%$$

Firm *B*, Profit $= [(10 - 5) \times 80000 \times 0.75 - 200000]$
$= ₹100000$

$$\% \text{ decrease in profit} = \frac{200000 - 100000}{200000} \times 100\% = 50\%$$

Firm *C*, Profit $= [(10 - 4) \times 80000 \times 0.75 - 324000] = ₹36000$

$$\% \text{ decrease in profit} = \frac{156000 - 36000}{156000} \times 100\% = 76.923\%$$

**Example 1.7** A component can be manufactured in either of two machines. Operating details of the two machines are given below:

| | 1st Machine | 2nd Machine |
|---|---|---|
| Number of pieces produced/hour | 20 | 60 |
| Cost of tooling | ₹ 100 | ₹ 210 |
| Setting time | 60 min | 240 min |
| Machining labour/hour | ₹ 4 | ₹ 4 |
| Setting labour/hour | ₹ 15 | ₹ 20 |
| Overhead charges | 3 times total labour cost | 10 times total labour cost |

Determine:

(i) Break-even quantity for production of the component

(ii) Compare economy of the two processes after the break-even point.

**Solution:**

Total cost = Tooling cost + Setting cost + Machine cost + Overhead cost

Let breakeven quantity be $x$ units.

$\therefore$ Total cost = (Tooling cost) + (Setting time × Setting labour/hr)

$$+ \frac{\text{Machining labour per hr} \times \text{Number of piece produced}}{\text{Number of piece produced per hr.}}$$

+ Overhead charges

For Machine 1:

$$\text{Total cost} = 100 + \frac{60}{60} \times 15 + \frac{4x}{20} + 3\left[\frac{60}{60} \times 15 + \frac{4x}{20}\right] = 100 + 15 + \frac{x}{5} + 3\left[15 + \frac{x}{5}\right]$$

$$TC_1 = 160 + \frac{4x}{5}$$

For Machine 2:

$$\text{Total cost} = 210 + \frac{240}{60} \times 20 + \frac{4x}{60} + 10\left[\frac{240}{60} \times 20 + \frac{4x}{60}\right] = 210 + 80 + \frac{x}{15} + 10\left[80 + \frac{x}{15}\right]$$

$$TC_2 = 1090 + \frac{11x}{15}$$

For break even quantity,

$$TC_1 = TC_2$$

$$\Rightarrow \quad 160 + \frac{4x}{5} = 1090 + \frac{11x}{15}$$

$$\Rightarrow \quad \frac{x}{15} = 930 \Rightarrow x = 13950 \text{ units}$$

∴ Break even quantity for production of the component = 13950 units

(ii) For $x = 13900$

$$TC_1 = 160 + \frac{4 \times 13900}{5} = ₹11280$$

$$TC_2 = 1090 + \frac{11 \times 13900}{15} = ₹11283.33$$

For $x = 14000$ units,

$$TC_1 = 160 + \frac{4 \times 14000}{5} = ₹11360$$

$$TC_2 = 1090 + \frac{11 \times 14000}{15} = ₹\,11356.67$$

∴ If $x < 13950$ units, we should go with 1st machine.

If $x > 13950$ units, we should go with 2nd machine

**Example 1.8** A company studied the cost data on quality and found a relationship between the percentage defective and the cost of control and cost of failure per 100 parts are as under:

Cost of failure, $F = 1500 + 120x$

Cost of control, $C = \frac{3000}{x}$

Where $x$ is percentage defective?

What is the percent defective which minimizes the quality cost? How much is the minimum quality cost per hundred parts?

**Solution:**

$$F = 1500 + 120x$$

$$C = \frac{3000}{x}$$

$$\therefore \quad \text{Quality cost, } T = F + C = 1500 + 120x + \frac{3000}{x}$$

For quality cost to be minimum,

$$\frac{dT}{dx} = 0$$