

Learning Curve Theory

BASIC CONCEPTS AND FORMULA

Basic Concepts

1. Learning Curve

Learning curve is a geometrical progression, which reveals that there is steadily decreasing cost for the accomplishment of a given repetitive operation, as the identical operation is increasingly repeated. The amount of decrease will be less and less with each successive unit produced. The slope of the decision curve is expressed as a percentage. The other names given to learning curve are Experience curve, Improvement curve and Progress curve.

2. The Learning Curve Ratio

In the initial stage of a new product or a new process, the learning effect pattern is so regular that the rate of decline established at the outset can be used to predict labour cost well in advance. The effect of experience on cost is summaries in the learning ratio or improvement ratio:

$$\frac{\text{Average labour cost of first } 2N \text{ units}}{\text{Average labour cost of first } N \text{ units}}$$

3. Learning Curve Equation

Mathematicians have been able to express relationship in equations. The basic equation

$$Y_x = KX^s$$

...(1)

where,

X is the cumulative number of units or lots produced

Y is the cumulative average unit cost of those units X or lots. K is the average cost of the first unit or lots is the improvement exponent or the learning coefficient or the index of learning which is calculated as follows:

$$s = \log \text{ of learning ratio} / \log 2$$

Question 1

Discuss the application of the learning curve.

Answer

Application of Learning curve: Learning curve helps to analyse cost-volume profit relationships during familiarisation phase of product or process to arrive at cost estimates.

It helps in budgeting and profit planning.

It helps in pricing and consequent decision making – e.g. acceptance of an order, negotiations in establishing contract prices etc. with the advantage of the knowledge of decreasing unit cost.

It helps in setting standards in the learning phase.

Question 2

What are the distinctive features of learning curve theory in manufacturing environment? Explain the learning curve ratio.

Answer

As the production quantity of a given item is doubled, the cost of the item decreases at a fixed rate. This phenomenon is the basic premise on which the theory of learning curve has been formulated. As the quantity produced doubles, the absolute amount of cost increase will be successively smaller but the rate of decrease will remain fixed. It occurs due to the following distinctive features of manufacturing environment:

- (i) Better tooling methods are developed and used.
- (ii) More productive equipments are designed and used to make the product.
- (iii) Design bugs are detected and corrected.
- (iv) Engineering changes decrease over time.
- (v) Earlier teething problems are overcome.
- (vi) Rejections and rework tend to diminish over time.

In the initial stage of a new product or a new process, the learning effect pattern is so regular that the rate of decline established at the outset can be used to predict labour cost well in advance. The effect of experience on cost is summarized in the learning curve ratio or improvement ratio.

$$\text{Learning curve ratio} = \frac{\text{Average labour cost of first } 2N \text{ units}}{\text{Average labour cost of first } N \text{ units}}$$

For example, if the average labour cost for the first 500 units is ₹ 25 and the average labour cost for the first 1,000 units is ₹ 20, the learning curve ratio is ($\text{₹ } 20/25$) or 80%. Since the average cost per unit of 1,000 units is ₹ 20, the average cost per unit of first 2,000 units is likely to be 80% of ₹ 20 or ₹ 16.

Question 3

M Ltd. Manufactures a special product purely carried out by manual labour. It has a capacity of 20,000 units. It estimates the following cost structure:

<i>Direct material</i>	<i>30 ₹ / unit</i>
<i>Direct labour (1 hour / unit)</i>	<i>20 ₹ / unit</i>
<i>Variable overhead</i>	<i>10 ₹ / unit</i>

Fixed overheads at maximum capacity is ₹ 1,50,000.

It is estimated that at the current level of efficiency, each unit requires one hour for the first 5,000 units. Subsequently it is possible to achieve 80% learning rate. The market can absorb the first 5,000 units at Rs.100 per unit. What should be the minimum selling price acceptable for an order of 15,000 units for a prospective client?

Answer

	5,000 units	20,000 units
Material	1,50,000	6,00,000
Direct Labour	1,00,000	2,56,000
		Refer to W Note i
Variable Overhead	<u>50,000</u>	<u>2,00,000</u>
Total Variable Cost	3,00,000	10,56,000
Fixed Cost	<u>1,50,000</u>	<u>1,50,000</u>
Total Cost	4,50,000	12,06,000
Total cost / unit	90	60.3
Sales 100 ´ 5,000	5,00,000	<u>5,00,000</u>
15,000 ´ x(assumed selling price)		15,000 x
(Total Sales less Total Cost) = Profit	50,000	15,000 x – 7,06,000

Or minimum selling price = 50.4(refer to Working Note ii)

17.4 Advanced Management Accounting

Working Note: I

Units	Hours
5,000	5,000
10,000	$10,000 \times 1 \times .8 = 8,000$ hours
20,000	$20,000 \times 1 \times .8 \times .8 = 12,800$ hours

Working Note: II

$$15,000x - 7,06,000 > 50,000$$

$$15,000x > 7,56,000$$

$$\text{or } x > 50.4$$

Alternative Solution:

$$\text{Total cost / unit of capacity } 20,000 = 60.3$$

$$\text{Weighted average selling price} > 80.4$$

$$\text{i.e. } \frac{5,000 \times 100 + 15,000x}{20,000} > 60.3$$

$$= 5,00,000 + 15,000x > 60.3 \times 20,000$$

$$= 15,000x > 12,06,000 - 5,00,000$$

Or

$$15,000x > 7,06,000$$

$$x > 47.06$$

$$\text{Minimum price to cover production Cost} = 47.06$$

$$\text{Minimum price to cover same amount of profit} = 50.40 \text{ (refer to Working Note 1)}$$

Working Note 1

$$(-47.06 + 50.04) \times 15,000 \text{ units} = ₹ 50,000$$

Question 4

A company which has developed a new machine has observed that the time taken to manufacture the first machine is 600 hours. Calculate the time which the company will take to manufacture the second machine if the actual learning curve rate is (i) 80% and (ii) 90%. Explain which of the two learning rates will show faster learning.

Answer

- (i) Actual learning curve rate is 80%.

Time taken to produce the first machine = 600 hours

Average time taken to produce two machines = $600 \times 80\%$ hours
= 480 hours.Cumulative time taken to produce two machines = 480×2 hours
= 960 hours.Time taken to produce the second machine = $(960 - 600)$ hours
= 360 hours.

- (ii) Actual learning curve rate is 90%.

Time taken to produce the first machine = 600 hours

Average time taken to produce two machines = $600 \times 90\%$ hours
= 540 hours.Cumulative time taken to produce two machines = 540×2 hours
= 1080 hours.Time taken to produce the second machine = $(1080 - 600)$ hours
= 480 hours.

The time taken to produce the second machine is lower at 80% learning rate and hence 80% learning rate shows faster learning rate.

Question 5

The Gifts Company makes mementos for offering chief guests and other dignitaries at functions. A customer wants 4 identical pieces of hand-crafted gifts for 4 dignitaries invited to its function.

For this product, the Gifts Company estimates the following costs for the 1st unit of the product

	Rs./unit
Direct variable costs (excluding labour)	2,000
Direct labour (20 hours @ ₹ 50 hour)	1,000

90 % learning curve ratio is applicable and one labourer works for one customer's order.

17.6 Advanced Management Accounting

- (i) What is the price per piece to be quoted for this customer if the targeted contribution is Rs.1,500 per unit?
- (ii) If 4 different labourers made the 4 products simultaneously to ensure faster delivery to the customer, can the price at (i) above be quoted? Why?

Answer

(i)

		Rs/u
	1 st unit	Avg/u after 4 th at
Variable Cost	2000	2000
Labour	1000	810
Target Contribution		1500
Price to be quoted		4310 (Rs./u)

- (ii) No, the company cannot quote this price for varying products because the learning curve Ratio does not apply to non-repeated jobs. Each product will carry a different price according to its direct labour hours.

Question 6

The following information is provided by a firm. The factory manager wants to use appropriate average learning rate on activities, so that he may forecast costs and prices for certain levels of activity.

- (i) A set of very experienced people feed data into the computer for processing inventory records in the factory. The manager wishes to apply 80% learning rate on data entry and calculation of inventory.
- (ii) A new type of machinery is to be installed in the factory. This is patented process and the output may take a year for full fledged production. The factory manager wants to use a learning rate on the workers at the new machine.
- (iii) An operation uses contract labour. The contractor shifts people among various jobs once in two days. The labour force performs one task in 3 days. The manager wants to apply an average learning rate for these workers.

You are required to advise to the manager with reasons on the applicability of the learning curve theory on the above information.

Answer

The learning curve does not apply to very experienced people for the same job, since time taken can never tend to become zero or reduce very considerably after a certain range of output. This is the limitation of the learning curve.

- (i) Data entry is a manual job so learning rate theory may be applied. Calculation of inventory is a computerized job. Learning rate applies only to manual labour.
- (ii) Learning rate should not be applied to a new process which the firm has never tried before.
- (iii) The workers are shifted even before completion of one unit of work. Hence learning rate will not apply.

Question 7

PQ Ltd. makes and sells a labour-intensive product. Its labour force has a learning rate of 80%, applicable only to direct labour and not to variable overhead.

The cost per unit of the first product is as follows:

<i>Direct materials</i>	<i>10,000</i>
<i>Direct labour</i>	<i>8,000 (@Rs.4 per hour)</i>
<i>Variable overhead</i>	<u><i>2,000</i></u>
<i>Total variable cost</i>	<u><i>20,000</i></u>

PQ Ltd. has received an order from X Ltd. for 4 units of the product. Another customer, Y Ltd. is also interested in purchasing 4 units of the product. PQ Ltd. has the capacity to fulfill both the orders. Y Ltd. presently purchases this product in the market for Rs.17,200 and is willing to pay this price per unit of PQ's product. But X Ltd. lets PQ choose one of the following options:

- (i) *A price of Rs.16,500 per unit for the 4 units it proposes to take from PQ.*

Or

- (ii) *Supply X Ltd.'s idle labour force to PQ, for only 4 units of production, with PQ having to pay only Re. 1 per labour hour to X Ltd.'s workers. X Ltd.'s workers will be withdrawn after the first 4 units are produced. In this case, PQ need not use its labour for producing X Ltd.'s requirement. X Ltd. assures PQ that its labour force also has a learning rate of 80%. In this option, X Ltd. offers to buy the product from PQ at only Rs.14,000 per unit.*

X and Y shall not know of each other's offer.

17.8 Advanced Management Accounting

If both orders came before any work started, what is the best option that PQ may choose?

Present suitable calculations in favour of your argument.

Answer

Units	Average/ hrs/u.
1	2,000
2	1,600
4	1,280
8	1,024

Material Cost / u = 10,000

Variable cost = 2,000

Variable Cost = 12,000

Option I

If both the orders came together, learning rate 80% applies and 8 units can be made, with average time of 1,024 hours per unit.

Cost to PQ:

Variable cost excl. labour = Rs.12,000

Labour cost 1,024 hrs × 4 Rs./hr = ₹ 4,096

= Rs.16,096

In this case,

	Y	X	
Selling Price p. u.	Rs.17,200	Rs.16,500	→ (under option I)
Variable Cost p. u.	<u>Rs.16,096</u>	<u>Rs.16,096</u>	
Contribution p. u.	Rs.1,104	Rs.404	
No. of units	4	4	
Contribution (Rs.)	4416	1616	6032

Option II

If X Ltd supplies its labour. 80% learning curve will apply to 4 units each of PQ & X.

Hence: hrs/ u = 1280

	Y	X	
Selling Price	Rs.17,200	Rs.14,000	
Variable Cost (excl. labour)	Rs.12,000	Rs.12,000	
Labour cost:			
1280 × 4	Rs.5,120		
1280 × 1	—	<u>Rs.1280</u>	
Total Variable Cost	<u>Rs.17,120</u>	<u>Rs.13,280</u>	
Contribution	Rs.80	Rs.720	
Units	4	4	
Contribution (Rs.)	320	2,880	3,200

PQ should not take labour from X Ltd. It should choose option I.

Question 8

Explain distinctive features of learning curve theory in manufacturing environment.

Answer

The production quantity of a given item doubled the cost of that item decrease at a fixed rate. This phenomenon is the basic premise on which the theory of learning curve has been formulated.

The distinctive features of a learning curve are:

1. Better tooling methods are developed and used
2. More productive equipments are designed and used to make the product.
3. Design bugs are detected and corrected.
4. Better design engineering reduces material and labour costs.
5. Early teething problems are overcome. As production progresses management is prompted to achieve better planning and better management.
6. Rejections and rework tend to diminish over time.
7. As quantity produced increases the Cost per unit decreases, since each unit entails:
 - (i) Lesser labour
 - (ii) Greater productivity of material and labour
 - (iii) Fewer delays and lesser time losses.

Question 9

An electronics firm which has developed a new type of fire-alarm system has been asked to quote for a prospective contract. The customer requires separate price quotations for each of the following possible orders:

17.10 Advanced Management Accounting

Order	Number of fire-alarm systems
First	100
Second	60
Third	40

The firm estimates the following cost per unit for the first order:

Direct Materials	₹ 500
Direct Labour	
Deptt. A (Highly automatic)	20 hours at ₹ 10 per hour.
Deptt. B (Skilled labour)	40 hours at ₹ 15 per hour.
Variable overheads absorbed	20% of direct labour
Fixed overheads absorbed	
Deptt. A	₹ 8 per hour
Deptt. B	₹ 5 per hour

Determine a price per unit for each of the three orders, assuming the firm uses a mark up of 25% on total costs and allows for an 80% learning curve. Extract from 80% learning curve table:

X	1.0	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
Y(%)	100.0	91.7	89.5	87.6	86.1	84.4	83.0	81.5	80.0

X represents the cumulative total volume produced to date expressed as a multiple of the initial order.

Y is the learning curve factor, for a given X value, expressed as a percentage of the cost of the initial order.

Answer

(i) Price /Unit for First 100 Units

		₹
Direct materials		500
Direct labour : Deptt. A 20 hrs. @10	200	
Deptt. B 40 hrs. @ 15	600	800
Variable O/H 20% of ₹ 800/-		160
Fixed O/H Deptt. A 20 hrs. @ 8	160	

Deptt. B 40 hrs @ 5	200	360
Total cost		1,820
Profit		455
Selling price per unit		2,275

(ii) Price/Unit for Second Order of 60 Units :

Learning will be applicable only in Dept. B

Cumulative output becomes 100 units + 60 units = 160 units

i.e. 1.6 times for which learning is 86.1% from the table.

\ total hours for 160 units = $160 \times 40 \times 0.861 = 5510.4$ units.

\ hours for 60 units = Hrs for 160 units – Hrs for 100 units.
= $5510.40 - 4000$ hrs = 1510.40 hrs.

\ Hours per unit = $1510.40 / 60 = 25.17$

Calculation of selling Price unit :

		₹
Direct materials		500.00
Direct labour: Deptt. A 20 hrs@ 10	200.00	
Deptt. B 25.17 hrs@ 15	<u>377.55</u>	577.55
Variable O/H 20% of ₹ 577.55		115.51
Fixed O/H : Deptt. A 20 hrs@ 8	160.00	
Deptt. B 25.17@ 5	<u>125.85</u>	<u>285.85</u>
Total Cost	1478.91	
Profit		<u>369.73</u>
Selling price per unit		1848.64

(iii) Price/Unit for Third Order of 40 Units:

Cumulative Output becomes $100+60+40 = 200$ units

i.e. 2 times for which Learning is 80% from the table

\ Total hours for 200 units = $200 \times 40 \times .80 = 6400$ hrs

\ Hours for 40 units = Hrs for 200 units – Hrs for 160 units. = $6400 - 5510.4 = 889.6$ hrs.

\ Hours per unit = $889.6/40 = 22.24$ hrs

Calculation of selling price/ unit :

Direct material	500 00
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17.12 Advanced Management Accounting

Direct labour: Deptt. A 20 hrs @ 10	200.00
Deptt. B 22.24 hrs @ 15	333.60
Variable O/H 20% of ₹ 533.60	106.72
Fixed O/H : Deptt. A 20 hrs @ 8	160.00
Deptt. B 22.24 @ 5	<u>111.20</u>
Total Cost	1411.52
Profit	<u>352.88</u>
Selling Price/Unit	<u>1764.40</u>

Alternative solution

Particulars	Amt. in First order	Second Order at *86.1%	Third Order at **80%
	(₹)	(₹)	(₹)
Direct Material	500.00	500.00	500.00
Direct Labour			
Dept A (20 hours @ ₹ 10 per hour)	200.00	200.00	200.00
Dept B (40 hours @ ₹ 15 per hour)	600.00	516.60	480.00
Variable overheads (20% of direct labour)	160.00	143.32	136.00
Fixed Overheads			
Dept A (20 hours @ ₹ 8 per hour)	160.00	160.00	160.00
Dept B (40 @ ₹ 5 per hour)	200.00	172.20	160.00
Total Cost	1820.00	1692.12	1636.00
Profit (25% of Cost)	455.00	423.03	409.00
Selling Price per Alarm	2275.00	2115.15	2045.00

Note : Learning Curve is not applicable for Department A as it is highly automated.

*Second Order – 60 fire-alarms, Cumulative Total = 160 fire-alarms

The cumulative total is now 160 Alarm, which is denoted by the multiple of 160/100 i.e. 1.6. From the 80% learning curve table the relevant percentage factor is 86.1% of the labour cost.

Cumulative order 160 @ ₹ 2115.15	3,38,424
Previous order 100 @ ₹ 2275	2,27,500
Increment order 60	1,10,924
Therefore, charge price per Alarm	1848.73

****Third Order-40 Alarm, Cumulative Total = 200 Alarm**

The cumulative total is now 200 fire alarms, which is denoted by the multiple of 200/100 i.e. 2. From the 80% learning curve table the relevant percentage factor is 80% of the labour cost.

Cumulative orders 200 @ ₹ 2045	409000
Previous order 160 @ 2115.15	338424
Incremental order 40	70576
Therefore, charge price per Alarm (₹)	1764.40

EXERCISE

Question 1

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Variable overheads	20% of direct labour
Fixed overheads absorbed:	
Deptt. A	₹ 8 per hour
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Determine a price per unit for each of the three orders, assuming the firm uses a mark up of 25% on total costs and allows for an 80% learning curve. Extract from 80% Learning curve table:

X	1.0	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
Y%	100.0	91.7	89.5	87.6	86.1	84.4	83.0	81.5	80.0

17.14 Advanced Management Accounting

X represents the cumulative total volume produced to date expressed as a multiple of the initial order.

Y is the learning curve factor, for a given X value, expressed as a percentage of the cost of the initial order.

Answer

(i) Price per unit for first order of 100 units

Selling price per unit = ₹ 2,275.00

(ii) Price per unit for second order of 60 units

Selling price per unit = ₹ 1,848.64

(iii) Price per unit for third order of 40 units

Selling price per unit = ₹ 1,764.40

Question 2

Explain the concept 'Learning curve'. How can it be applied for Cost management?

Answer

Chapter 17: Paragraph 17.5