Chapter 2

Learning curve theory

2.1 Learning or experience curve theory

Learning curve theory is the theory that as output doubles the average time per unit (total time for all units divided by the units produced) drops by a fixed percentage each time this happens. The same theory can be applied to find the average cost per unit as well as the average time.

Assumptions

- Heavy manual element in production and so scope for learning.
- Repetitive work so therefore speed and accuracy can be improved.
- Production is in its early stages and so no great improvements have been made.
- Consistency in the workforce means that the same workers are used.
- No extensive breaks in production so that the skills and techniques learned are retained.

Learning curve theory can be illustrated using the following data:

If one unit takes 10 hours to produce then

- Would 2 units take 20 hours to make?
- Would 4 units take 40 hours to make?

If labour can learn or gain by experience, then the answer should be 'no' and average labour hours per unit would fall.

If it is found that an 80% learning curve applies, it means that each time output doubles on a cumulative basis, the cumulative average labour hours per unit fall by 20%

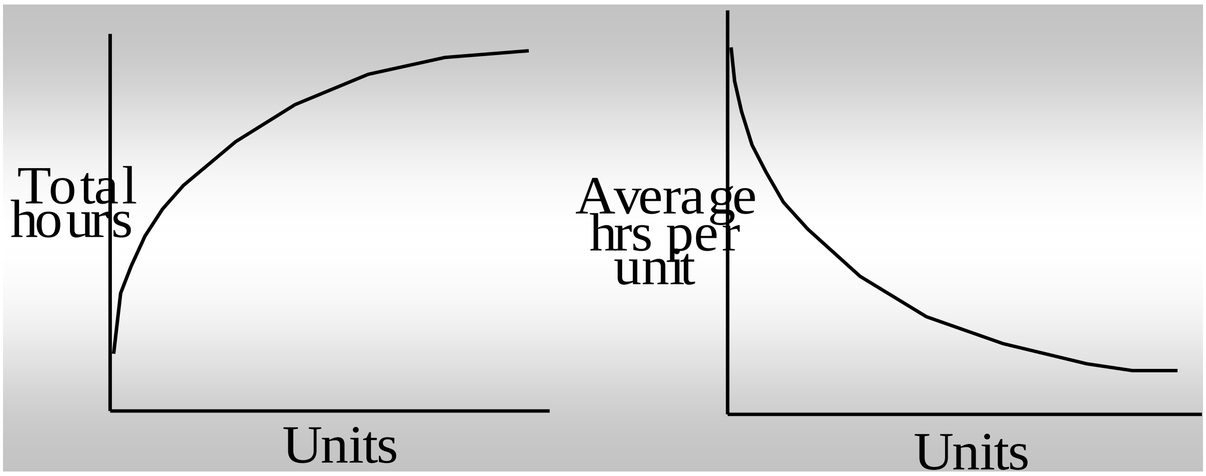
Thus

		Average hours/unit
1 unit takes	10 hours	10
2 units takes	(2 × 10) × 80% = 16 hrs	8
4 units takes	(4 × 10) × 80% × 80% = 25.6 hrs	6.4
8 units takes	(8 × 10) × 80% × 80% × 80% = 40.96 hrs	5.12

Note that the average hours per unit falls to 80% of its previous level each time cumulative output doubles.

This could only occur where labour can learn and therefore influence the time taken; it clearly could not apply where the rate of production is machine or process controlled.

The learning curve can be plotted on normal graph paper.



Application of learning curve theory

Product pricing - in a competitive situation, pricing on long run average costs can consider the extent to which costs will fall because of the learning curve effect.

Setting standards for cost centres - if labour performance is to be judged against a standard cost, the standard should reflect anticipated learning benefits.

Budgeting for manpower needs - if learning is **not** considered, over manning could result when new working practices are being introduced.

Formulae

$Y = aX^b$

Y = average time for that (X) number of units or the average cost per unit
a = time for the first unit or the cost for the first unit
X = the number of units you want to calculate an average time or cost for
b = the index of learning (log r/log 2)

If the learning rate of the workforce was 90% (r = 0.9) then the average time or cost per unit falls by 10% each time output doubles.

Learning curves are relevant when the process is labour intensive or new product therefore new processes are being introduced for the first time. It is likely to affect variable overhead as well as your labour cost. The experience curve is the same principle however is more relevant to falling cost, due to technological, organisational changes and management experience or knowledge gained over many years rather than just learning new skills.

The learning curve formulae can be developed to calculate the total time or total cost for the cumulative X units by adding +1 to the power b as follows:

Total Time (or cost) for X units = aX^{b+1}

Example 2.1

Locus cars are a company set up in London to build mass-produced sports cars. 5 skilled workmen working a standard 35-hour week will build these cars. Production has only just started but the workforces are keen to learn quickly.

The first prototype was built however; the time taken had not been recorded. The third unit however did record that the average time for all units at this point was 11.36 hours. Based on previous knowledge, management believe there is a 70% learning rate of the new workmen.

a) **Calculate the time taken for the first prototype?**

b) **Calculate the total time taken for the 12th car only?**

c) **Calculate the total time for the 14th to the 15th car only?**

d) **How many cars can Locus build in the first 2 months assuming the learning effect ceases at 200 cars?**

e) **Locus cars have also built tractors in the past, and they had built 8 of them. The first tractor took 17 hrs of labour time and the total time for the first 8 tractors was 100 hrs. Calculate the learning curve to the nearest 1%.**

2.2 Pareto analysis

> ‘Vilfredo Pareto (an Italian economist) once stated that 20% of the population of Italy at that time accounted for 80% of the countries wealth’

Such analysis does not always give an exact 20/80 relationship however is still useful to determine what is important.

20% of stock lines could be up to 80% of the value of total stock.

20% of customers could account for 80% of your sales and the same 20% may or may not account for 80% of your profit or contribution..

20% of your cost drivers could account for 80% of your fixed overhead when using an ABC system.

All the above examples help understand your position better. A Pareto analysis applied to stock above could mean that if a company did not worry too much about the immaterial components or raw material value, it could consume less overhead in doing so and manage stock more efficiently. In the case of sales above, more client care could be devoted to those customers generating the most income or profit for the company.

Example 2.2 – Worked example

The monthly sales of a company's four main product groups has been analysed as given below. It is desired to know whether it conforms to a Pareto distribution.

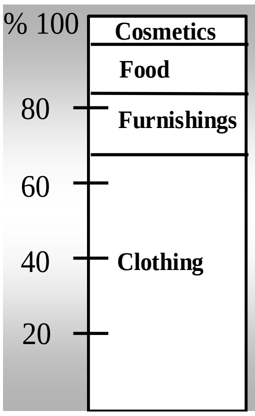
Product group	***Monthly Sales (£'000)***
Food	228
Cosmetics	15
Clothing	942
Furnishings	315
	1,500

Solution

- ***Note:*** product groups should be accumulated in **descending** order of value

Product Group	***Sales (£'000)***	***%***	***Cum. %***
Clothing	942	62.8	62.8
Furnishings	315	21.0	83.8
Food	228	15.2	99.0
Cosmetics	15	1.0	100.0
	1,500		

Pareto diagram



Comment

Just over 80% of the company's total turnover is generated by 2 (of 4) of the divisions, illustrating an uneven (80/50) distribution, not quite in line with the 80/20.

An alternative presentation could also have been to represent the above as a Pareto curve.

Example 2.3

Pet rescue centre has been raising funds by asking donators to sponsor an animal **that may never have a loving home.** Details about the number of sponsorships received over the last 4 months are as follows;

	£
Reptiles	4,000
Puppies	15,000
Apes	1,000
Kittens	3,000
Hamsters	600
Rats	200
Fish	1,000
Chinchillas	100
Total	24,900

Conduct a Pareto analysis on the above information, to decide the most popular animals that they should use in order to generate more income?

Key summary of chapter

Learning curve theory - output doubles the average time per unit drops by a fixed percentage.

$Y = aX^b$

Y = average time for that (X) number of units or the average cost per unit
a = time for the first unit or the cost for the first unit
X = the number of units you want to calculate an average time or cost for
b = the index of learning (log r/log 2)

Total Time (or cost) for X units = aX^{b+1}

Pareto analysis – helps in determining what is important for example 20% of a data set could account for 80% of the activity.

Solutions to lecture examples

Chapter 2

Example 2.1

Calculate the time taken for the first prototype?

Log 0.7/log 2 = -0.5146

11.36 hours = a x 3 (to the power of –0.5146)

11.36 = a x 0.5682

a = 11.36/0.5682

a = 20 hours

Calculate the total time taken for the 12th car only?

Time for the first 12 units (20 x 12 (to the power of –0.5146) x 12 =	66.81 hours
Time for the first 11 units (20 x 11 (to the power of –0.5146) x 11 =	(64.05) hours
Time for the 12th unit	2.76 hours

Calculate the total time for the 14th to the 15th car only?

Time for the first 15 units (20 x 15 (to the power of –0.5146) x 15 =	74.46 hours
Time for the first 13 units (20 x 13 (to the power of –0.5146) x 13 =	(69.46) hours
Time for the 14th to 15th unit	5.00 hours

How many cars can Locus build in the first 2 months assuming the learning effect ceases at 200 cars?

Time for the first 200 units (20 x 200 (to the power of –0.5146) x 200 =	261.8
Time for the first 199 units (20 x 199 (to the power of –0.5146) x 199 =	(261.2)
Time for the 200th unit	0.6

Workmen work in 2 months (8 weeks x 5 men x 35 hrs) 1,400 hours

The first 200 units take 261.8 hours as above

1,400 hours less 261.8 hours = 1,138.2 hours remaining

1,138.2 hours/ 0.6 hours (time for the 200th unit and beyond) =1,897 units

Therefore 200 units + 1,897 units = 2,097 cars built in the first 2 months

Locus cars have also built tractors in the past, and they had built 8 of them. The first tractor took 17 hrs of labour time and the total time for the first 8 tractors was 100 hrs. Calculate the learning curve to the nearest 1%.

a = 17 hrs, y = 100 hrs / 8 tractors = 12.5 hrs on average for 8 tractors

If we assume that "r" represents the learning rate, then:

Tractors	Average hours per unit
1	17
2	17 x r
4	17 x r x r
8	17 x r x r x r

Therefore for 8 tractors:
$17r^3 = 12.5$
$r^3 = 12.5 / 17$
$r^3 = 0.735294117$
r = (0.735294117) to the power of 1/3
r = 0.90

Therefore learning rate is 90%

Example 2.3

Note: product groups should be accumulated in **descending** order of value

Product Group	***Sales (£'000)***	***%***	***Cum. %***
Puppies	15,000	60.2	60.2
Reptiles	4,000	16.1	76.3
Kittens	3,000	12.1	88.4
Apes	1,000	4.0	92.4
Fish	1,000	4.0	96.4
Hamsters	600	2.4	98.8
Rats	200	0.8	99.6
Chinchillas	100	0.4	100.0
Total	24,900	100.0	

A Pareto curve or bar chart could be produced with the above information. There exists a 76.3%/25% relationship between puppies and reptiles indicating that these are the biggest revenue earners in the case of sponsorship revenue received. Pet Rescue should therefore concentrate on these two animals or perhaps kittens as well in order to increase the effectiveness of donations received (if you include kittens there exists an 88.4%/37.5% relationship above).