The learning curve: from aircraft to spacecraft?

G.J. Steven, Napier University

While this article was principally written for Management Accounting Applications, it is also relevant for Management Science Applications (MSA). MSA students, however, are only expected to have knowledge of this technique, i.e. no calculations are required for this technique at Stage 2.

Introduction
The learning curve was first observed by Wright in the 1930s in the American aircraft industry, and his pioneering work was confirmed by Crawford in the 1940s. But what is the learning effect? Where can it be used? What can it be used for? And is it relevant for the modern business environment?

Economies of scale
Most students will be familiar with economies of scale. However, it is important to appreciate that the learning effect is not concerned with reduction in unit cost as production increases and/or production facilities are scaled up to manufacture larger batches of products. So what is the learning effect?

Learning effect
The learning effect is concerned with cumulative production over time—not the manufacture of a single product/batch at a particular moment in time—and recognises that it takes less time to assemble a product the more times that product is made by the same worker, or group of workers.

The most effective way of describing the learning effect is to consider the assembly of self-assembly furniture in your own home! Let’s assume that you decide to purchase three self-assembly chests of drawers for your home.

The first chest of drawers will take considerable time to assemble since you are unfamiliar with the instructions, the components, and how to assemble them. In addition, you may also lack confidence in your ability to produce an acceptable product.

The second one, however, will take you less time, as you will be more familiar with the instructions, the components, and the assembly procedures. You will also be confident of your ability to assemble this product.

The third one will take even less time, as you will have learned from your earlier mistakes and determined more efficient assembly procedures. That is the learning effect.

Cost reduction tool?
It is important to appreciate that the learning curve is not a cost-reduction technique since the rate of future time reduction can be predicted accurately by the learning curve model. Cost reduction only occurs if management action is taken, for example, to increase the rate of time reduction by providing additional training, provision of better tools etc.

The learning effect occurs because people are inventive, learn from earlier mistakes, and are (generally) keen to take less time to complete tasks, for a variety of reasons. It should also be noted that the learning process may be done consciously and/or intuitively. The learning curve consequently reflects human behaviour.

Learning curve sectors
While the learning curve can be applied to many sectors, its impact is most pronounced in sectors which have repetitive, complex operations where the pace of work is principally determined by people, not machines. If the pace of work is determined by machines, the learning effect will not be observed since (at present!) people learn, not machines.

Examples of sectors where the learning effect is pronounced include:
- aerospace;
- electronics;
- shipbuilding;
- construction;
- defence.

The learning curve is also being utilised by the refurbishment sectors. Rail operators, for example, seek to extend cost-effectively the lives of their assets, e.g. London Underground, privatised rail companies etc.

Another sector which makes considerable use of this technique is the space industry. NASA, for example, uses the learning curve to estimate costs for the production of space shuttles, time to complete tasks in space etc. The phenomenon observed by Wright and Crawford is now being used for extra terrestrial activities!

Learning curve model
Wright observed that the cumulative average time per unit decreases by a fixed percentage each time cumulative production doubles over time. The following table illustrates this effect:

<table>
<thead>
<tr>
<th>Cumulative output</th>
<th>Cumulative time</th>
<th>Average time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 unit</td>
<td>1,000 hrs</td>
<td>1,000 hrs</td>
</tr>
<tr>
<td>2 units</td>
<td>1,800 hrs</td>
<td>900 hrs</td>
</tr>
<tr>
<td>4 units</td>
<td>3,240 hrs</td>
<td>810 hrs</td>
</tr>
<tr>
<td>8 units</td>
<td>5,832 hrs</td>
<td>729 hrs</td>
</tr>
</tbody>
</table>

The above table indicates that the cumulative average time per unit falls by 10% each time cumulative production doubles, i.e. it is depicting a 90% learning curve.

The above relationship between cumulative output and time can be represented by the following formula:

\[ Y_x = ax^b \]

where \( Y_x \) = cumulative average time to produce a cumulative number of units
\( a = \) time to produce the first unit
\( x = \) cumulative number of units
\( b = \) index of learning

The index of learning is the log of the learning curve divided by the log of 2.

NB: At present, CIMA does not require students to calculate the index of learning.

Use your calculator to confirm that \( b = -0.152 \) for a learning rate of 90%.

Calculator instructions
Press \( \text{LOG} \)
Enter 0.9
Press \( \text{DIVIDE} \)
Press \( \text{LOG} \)
Enter 2
Press \( \text{EQUALS} \) to obtain answer, i.e. -0.152

NB: The above instructions may not apply to all types of scientific calculator and the cumulative average time per unit is 7,329 hours for a cumulative output of eight units.
Dark Star project, experimental Stealth aircraft to those recently supplied by the company for the Aurora project, the new potential contracts in sectors which exhibit the technique can also be used to determine costs for new contracts for the same, or a similar product. Customers are also increasingly aware of the learning effect, and expect better quality and lower prices. The learning curve is a vital decision-making tool, however, since it can be used to prepare competitive tenders by utilising earlier learning for new contracts for the same, or a similar, product.

### Conclusion

The learning effect, which was first recognised by Wright and Crawford, still applies to today’s business environment since people haven’t changed since the 1930s. It is also possible that the learning curve will be used more widely in the future due to the demand for sophisticated high-technology systems, and the increasing interest in refurbishment to extend asset life. While much has been written in relation to the use of the learning curve for budgeting and control, there has been little recognition of its potential for decision-making. The learning curve is a vital decision-making tool, however, since it can be used to prepare competitive tenders by utilising earlier learning for new contracts for the same, or a similar, product. Customers are also increasingly aware of the learning effect, and expect better quality and lower prices. The learning curve is a vital decision-making tool, however, since it can be used to prepare competitive tenders by utilising earlier learning for new contracts for the same, or a similar, product.

### References and further reading


**NASA** http://www.jsc.nasa.gov/bu2/learn.html