

DEFENSE SYSTEMS MANAGEMENT COLLEGE

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TEACHING NOTE

APPLICATION OF LEARNING CURVE THEORY TO SYSTEMS ACQUISITION

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INTRODUCTION

In the early 1930's, aircraft researcher T.P. Wright observed that the average cost to produce a production lot of airplanes decreased at a predictable rate as the size of the production lot increased. He theorized that this primarily occurred because the time required to perform a repetitive task will decrease each time the task is repeated. Wright's "Learning Curve" theory has become widely used because it is simple and applicable to a broad range of industries and situations. Subsequent research in the late 1940's by James R. Crawford confirmed Wright's observations and led to the unit theory of the learning curve which will be discussed in this note.

LEARNING CURVE THEORY

The unit theory of the learning curve states that as the quantity of a product produced doubles, the recurring cost per unit decreases at a fixed rate or constant percentage. The best way to understand this theory is to look at an example.

Example: The XYZ Widget Co. has gathered the following data on production costs of its new Super-Widget:

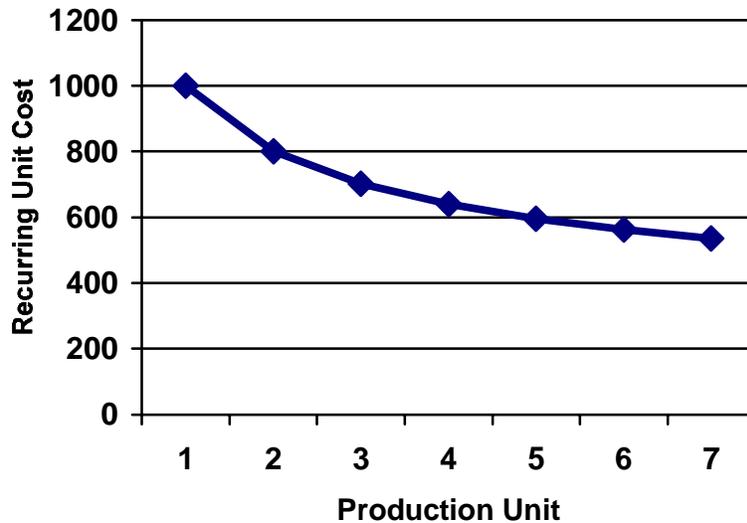
Unit	Recurring Unit Cost
1	\$1000
2	\$ 800
3	\$ 702
4	\$ 640
5	\$ 596
6	\$ 562
7	\$ 535

From this data, we can see that as production quantity doubled from Unit 1 to Unit 2, the recurring unit cost decreased by \$200, or 20% of the Unit 1 cost of \$1000. Note also that as production quantity doubled from Unit 2 to Unit 4, the recurring unit cost decreased by \$160, which is also a 20% decrease from the previous recurring unit cost of \$900 for Unit 2.

Based on this data and the learning curve theory, XYZ predicts that the recurring unit cost for Unit 8 will be 20% less than that of Unit 4, or \$512.

Plotted on an arithmetic graph (Figure 1), this data takes on a curved shape, hence the term “learning curve”.

Figure 1



The learning curve described in this example is called an “80% learning curve”, since the cost of a particular unit of production is 80% of the cost of the unit exactly half-way back in the production sequence. For example, just as Unit 4’s cost (\$640) is 80% of Unit 2’s cost (\$800), so Unit 8’s cost should be 80% of Unit 4’s cost, or \$512.

The mathematical equation which describes the unit learning curve theory described above is:

$$Y_X = AX^B \quad \text{where } Y_X = \text{Cost of Unit } X$$

$$A = \text{Cost of Unit 1}$$

$$B = (\log(\text{learning curve})) / (\log(2))$$

Learning Curve Theory is most straightforwardly applied in situations where the following conditions exist:

1. Uninterrupted serial production (i.e., no production breaks),
2. Consistent product design, and
3. Management emphasis on productivity improvement.

These conditions promote the behaviors underlying the decline of unit cost with increased production quantities:

1. Worker familiarization with the required tasks (learning), and
2. Process improvements resulting from experience with the tasks, e.g., more efficient layout of assembly line; simplification of methods sheets; reduction of rework, repair, and scrap; improved parts bin accessibility; new or improved tooling.

APPLYING LEARNING CURVE THEORY TO SYSTEM ACQUISITION

Learning curve theory should be applied to the production portion of a system's cost estimate. The challenge is determining the appropriate learning curve to use for a particular system. Ultimately, the only way to know the "true" learning curve for a particular system is to observe it after the fact. However, this is not useful when resource plans must be submitted years in advance of production. Therefore, most estimators will use historical data from other similar type systems to estimate the new system's learning curve.

Caution should be applied to simple straightforward use of historical learning curve data, however. The primary concern should be how well the historical data reflects the expected production conditions for the new system. To the extent that such production conditions differ from the past, the analyst should attempt to quantify the effects of the differences on the historical learning curve.

Some examples of production conditions that can affect a system's learning curve:

1. Manufacturing methods and processes. The less "touch" labor is involved in a production process (i.e, more automation), the *flatter* the learning curve will usually be, i.e., the value of the learning curve will tend to be higher. Thus, if the historical learning curve is 85% and the manufacturer intends to automate the production more than in the past, we would expect the learning curve for the new process to be something greater than 85% (e.g., 90%).

2. Item complexity. The more complex an item is, the *steeper* the learning curve will usually be. This is because there are more opportunities to improve the production process and more for workers to learn. Thus, if a historical item experienced a 93% learning curve, a new, more complex item of the same type would be expected to have a learning curve of less than 93% (e.g., 88%).

3. Workforce stability. The higher the turnover rate of the workforce, the flatter the learning curve will usually be, as average worker productivity increases will be inhibited by turnover.

4. Production breaks. Interrupting production can lead to changes in the historical learning curve. For example, if many new workers are assigned to the job after the production break, there may be a lack of experienced veterans to train new workers on the job, resulting in a flatter learning curve, at least initially, compared to the historical learning curve. In addition, even if a production break does not actually change the learning curve itself, the break will likely change *where* you are on the learning curve, as the workers tend to have lost some of their skills. Thus, if the production process had a 90% learning curve and 799 units were produced prior to the production break, the first unit after the production break (Unit 800) is unlikely to cost 90% of Unit 400's cost, as would have been expected without the break. Instead, Unit 800 may cost the same as some prior unit, say Unit 700. In this case, we have effectively *lost* 100 units for the purposes of learning curve effects.

It should also be noted that a system may not experience the same learning curve during its entire production run, depending on changes in conditions during the production run.