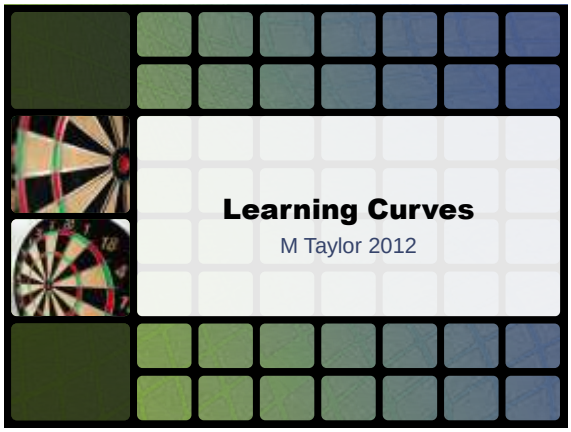


Agenda

- Learning Curve (LC) Concept
- LC in the real world
- The Curve
- Application

What is Learning Curve?

- Observed in aircraft manufacturing ~1940s
- Unit production time decreased with QTY
- When an task is performed repetitively, we "learn" and improve our speed an efficiency the more we repeat the task.
- At first, learning was attributed to increased motor skills in the workers as they repeated their tasks
  - Later it was realized that management also could contribute to learning with better tools and processes

The Learning Effect

- Production time decreased as production volume increased – by a exponential amount!

Two slightly different models in use

1= 100 hrs
2= 90 hrs
4= 81 hrs

- Time to produce a unit decreases by a fixed percentage each time the QTY produced is doubled (Unit Model)

or

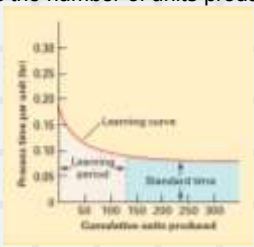
Same effect but different curves

- Cumulative Average time to produce the units decreases by a fixed percent

The Chart

Using a Log chart – the "curve " is a straight line. Handy for extrapolation or regression analysis

- Relationship between time to produce a unit vs the number of units produced



Note how an industry might use LC to find a "standard time"

Common Examples

- Bid Preparation: In a large job, how much time(labor) will it take to make all of the pieces?
- Financial Planning: Direct Labor costs will be higher early in a job than later
- Labor Requirements: To produce the required number of units per day will require fewer people the longer we make the item
- Home Building – If all houses in a development are built the same way – at the same time - the builder gets big benefits in reduced construction time.
- Management or production process improvements

Basic Relationship Formula

This formula is the basis of both models

$y = ax^b$

b is called the natural slope—it represents the rate of learning [always a negative number

The two models differ in their interpretation of *y* (next chart)

a always represents the theoretical labor hours required to build the first unit produced (a positive number)

x always represents the number (count) of an item in the production sequence (unit #1, #2, #3, etc.)

Model Comparison

Either could be 'more" correct for the specific task.

The curve that best fits the data is the one to use

- Unit (U) model
  - *y* is the labor hours required to build unit #*x*
    - Because of the negative slope(*b*), *y* decreases as *x* increases
- Cumulative average (CA) model
  - *y* is the average labor hours per unit required to build the first *x* units

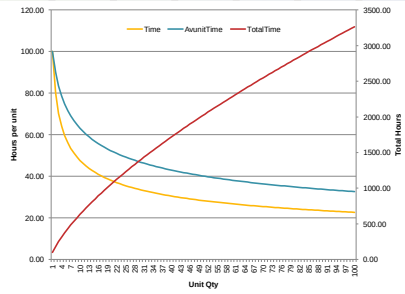
$H_n = H_1 n^b$

Hours to build unit #*n* | Hours to build unit #1 | Unit number | slope

90% Curve Relationship

Note similar curves just different slopes

Interesting: Notice the total time is not a straight line



The Slope

Source for industry figures, Galorath

- In industry, Slope typically seen from 70% to 100%
- It's counterintuitive, but 100% means no learning at all
- The highest rate of learning achieved in most industrial situations is about 70%
- LC could apply to different elements of a process at different slopes. Isolate the specific processes and analyze individually. Useful to prepare for eventual changes in the SOW.

Useful Formulas

U Model: If the slope is *S*%, any doubling of the production quantity from some unit #*n* to another unit #2*n* results in a reduction in labor hours from H_n to *S*% of H_n.

CA Model: If the slope is *S*%, the average hours for units 1 through 2*n* are *S*% of the average hours for units 1 through *n*.

Calculators - Examples

References at the end

- Calculate based on unit time or running average – slightly different curves with similar results.
- Use calculator tools to extrapolate or estimate
- Use actual data whenever possible to find the best curve and slope

Practical Application

- Fit learning curves to historical data when available
  - This is usually the best source, but not always indicative of the future
- Guidelines for use when historical data are not available:
  - Operations that are fully automated tend to have slopes of 100%, or a value very close to that (no learning can happen).
  - Operations that are entirely manual tend to have slopes in the vicinity of 70% (maximum learning can happen). (cont.)

Practical Application

- Guidelines (cont.)
  - If an operation is 75% manual and 25% automated, slopes in the vicinity of 80% are common.
  - If it is 50% manual and 50% automated, expect about 85%.
  - If it is 25% manual and 75% automated, expect about 90%.
  - The average slope for the aircraft industry is about 85%. But there are departments in a typical aircraft factory that may depart substantially from that value.
  - Shipbuilding slopes tend to run between 80 and 85%.

Practical Application

- The following typical values assume repetitive operations. They are not valid if operations are sporadic, as in a job shop environment.

Manufacturing Activity	Typical Slope %
Electronics	90-95
Machining	90-95
Electrical	75-85
Welding	88-92

Cal Poly Mgmt Course

One source of information

Discussion

- Commonly used in Manufacturing, financial management and cost estimating
- How could LC affect price?
- Which contracts would most likely benefit?
- Can a company or organization exhibit the effects of LC?

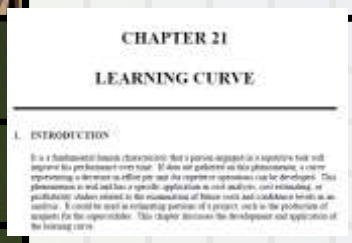
Issues / Impacts

- LC can be interrupted by down-time
- LC can be impacted by changes in production process or personnel
- LC is affected by changes in the SOW
- Curve could change or just jog up
- Process could be automated
- Customizing a product could change "standard time" **BUT** the customization process could have it's own LC

Resources

- Excel handout **(link)**
- DAU calculator excel (link)
- DOE Guide Chapter 21 (link)
- Business Analytics web page, includes description and a calculator (link)

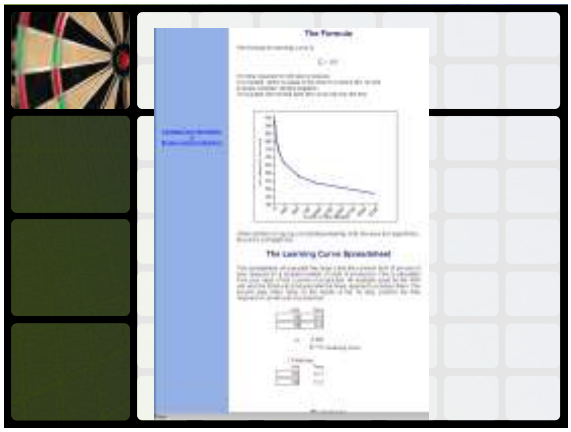
DOE guide

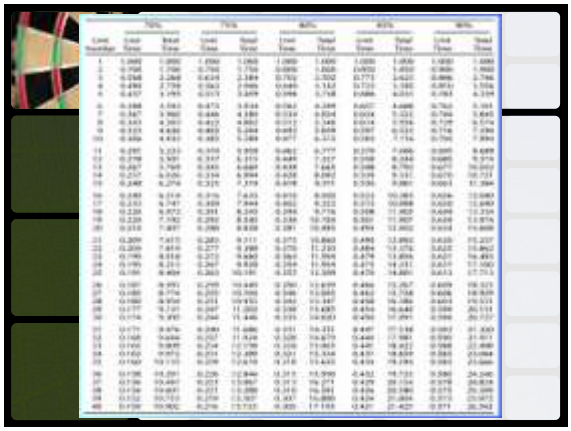


CHAPTER 21

LEARNING CURVE

1. INTRODUCTION





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