

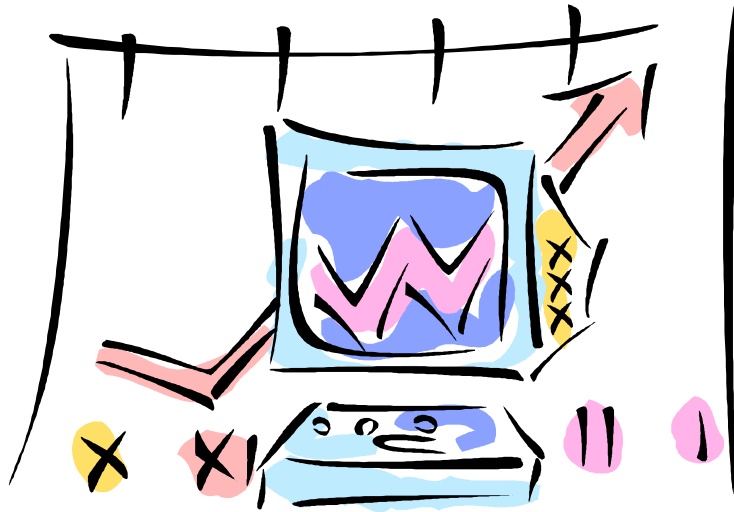
Cost Estimation

Learning Objectives

- Understand the strategic role of cost estimation
- Understand the six steps of cost estimation
- Apply and understand each of cost estimation methods: the high-low method and regression analysis
- Explain the implementation issues of the cost estimation methods

Learning Objectives (continued)

- Use learning curves to estimate a certain class of non-linear cost function



Strategic Role of Cost Estimation

- ***Cost estimation* is the development of the functional relationship between a cost object and its cost drivers for the purpose of predicting the cost**
- **Accurate cost estimates facilitate the strategic cost-management process in two ways:**
 - Cost estimates based on activity-based, volume-based, structural, and executional cost drivers facilitate effective planning, decision making, and performance measurement

Steps in Cost Estimation

There are six steps in the *cost estimation* process:

❶ Define the cost object to be estimated

❷ Determine the cost driver(s)

- The most important step: specification of underlying causal factors of a cost

❸ Collect consistent and accurate data

- *Consistent* means that the data are calculated on the same accounting basis and all transactions are recorded in the proper period
- *Accuracy* refers to the reliability of the data

Steps in Cost Estimation (continued)

④ Graph the data

- To identify unusual patterns, possible nonlinearities, and any outlier observations

⑤ Select and employ a cost-estimation method (e.g., linear regression)

⑥ Assess the accuracy of the cost estimate

- One measure of the accuracy of the estimation method is the *mean absolute percentage error* (MAPE) produced by that method

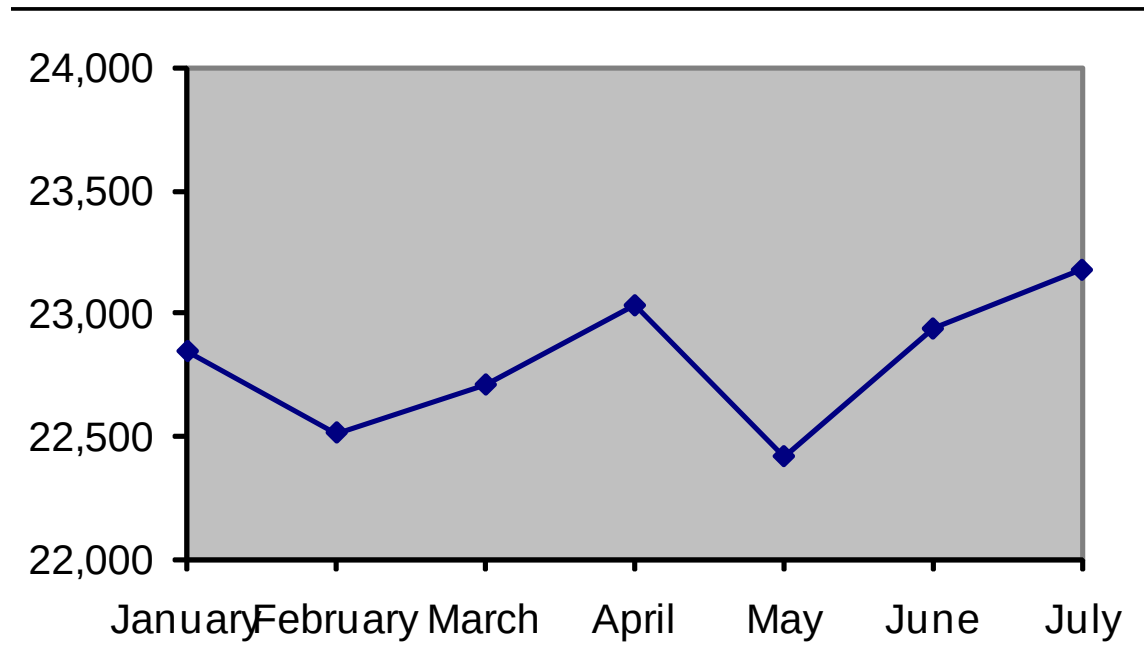
Cost Estimation Methods

- **There are two *cost estimation methods* :**
 - The High-Low method
 - Regression analysis (both linear and nonlinear models)
- **The High-Low method** is simpler but less accurate than the regression method.
- The method chosen by the cost analyst will depend on the level of accuracy desired and any limitations on cost, time, and effort

Cost Estimation: An Example

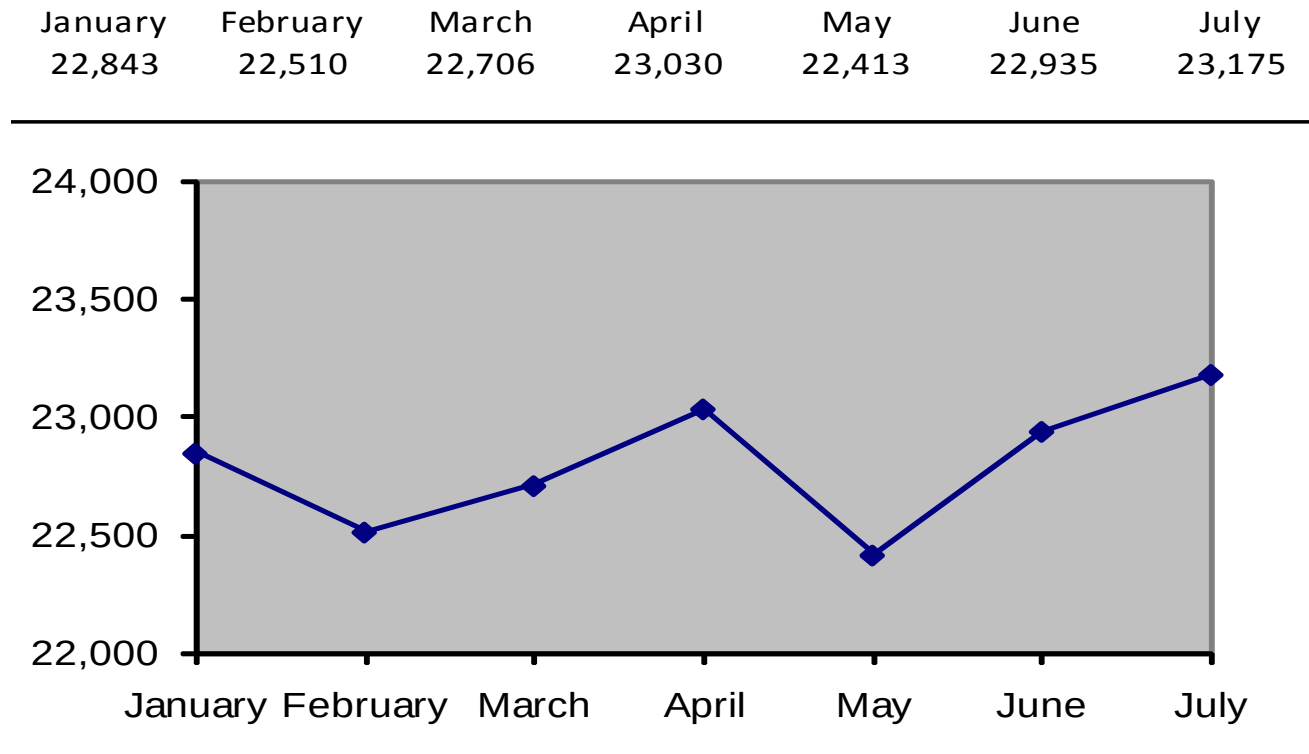
Bill Garcia, a management accountant, wants to estimate future maintenance costs for a large manufacturing company; recent monthly cost data are as follows:

January	February	March	April	May	June	July
22,843	22,510	22,706	23,030	22,413	22,935	23,175



Cost Estimation Example (continued)

Based on above information, Garcia feels that maintenance costs for August will likely be between \$22,500 and \$23,500, but he wants to be accurate so he considers cost estimation.



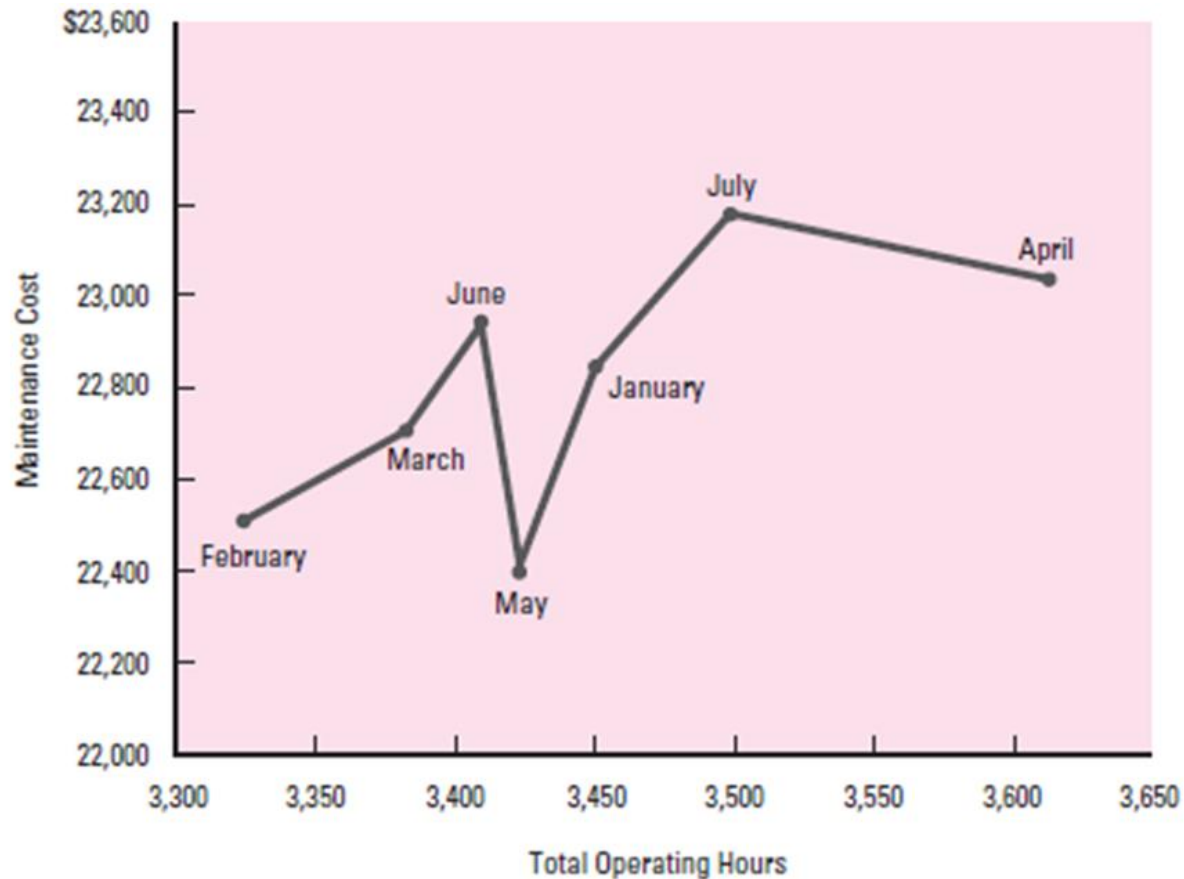
Cost Estimation Example (continued)

Garcia would like to estimate an underlying cost function for maintenance costs. Garcia feels there is an economic relationship between maintenance cost and monthly operating hours (a cost driver), so he collects the following monthly observations:

	January	February	March	April	May	June	July
Total operating hours	3,451	3,325	3,383	3,614	3,423	3,410	3,500
Maintenance costs (\$)	22,843	22,510	22,706	23,030	22,413	22,935	23,175

Cost Estimation Example (continued)

Another graph is created to incorporate the new data:



The High-Low Method

The *high-low method* uses algebra to determine a unique estimation line (equation) between representative high and low points in the data

- This method provides a unique cost line rather than a rough estimate based on a visual fitting of a cost function line through a set of data points
- The high-low equation is as follows:

$$Y = a + (bX)$$

Where Y = the value of the estimated cost

X = the cost driver

a = a fixed quantity that represents Y when X is zero

b = the slope of the line (unit variable cost)

The High-Low Method (continued)

- Using the graph, Garcia picks two data points, one representative of the lower points and one representative of the higher points (these points are often, but not necessarily, the highest and lowest points in the data set)
- Let us assume that Garcia picks from the data set February (low point) and April (high point)
- The next step is to calculate the equation of the line connecting these two points

The High-Low Method (continued)

	Hours	Cost
High Point (April)	3,614	\$ 23,030
Low Point (February)	<u>3,325</u>	<u>22,510</u>
Change	<u><u>289</u></u>	<u><u>\$ 520</u></u>

$b = \text{Unit variable cost} = \$520 \div 289 \text{ hours} = \$1.80/\text{hour}$

$a = \text{Fixed cost} = \text{Total cost} - \text{Estimated variable cost}$

$\text{Fixed cost} = \$23,030 - (\$1.80/\text{hour} \times 3,614 \text{ hours})$

$\text{Fixed cost} = \$23,030 - \$6,505 = \$16,525$

Estimated cost function:

$\text{Total cost} = \text{Fixed cost} + \text{Variable cost}$

$$Y = a + (b \times X)$$

$$Y = \$16,525 + (\$1.80 \times X)$$

The High-Low Method (continued)

For values of the cost driver (operating hours) within the “relevant range,” the preceding equation can be used to estimate monthly maintenance costs. For example, for the month of August:

Suppose that 3,600 operating hours are expected in August:

$$Y = 16,525 + (1.80 \times X)$$

$$Y = 16,525 + (1.80 \times 3,600)$$

$$Y = 16,525 + 6,480$$

$$Y = \$23,005 \text{ in maintenance costs}$$

The High-Low Method (continued)

Pros:

- Requires less effort and cost than regression analysis
- Provides a unique cost equation from which the management accountant can estimate future costs – useful in calculating total cost

Cons:

- Relies on only two points, and the selection of those two points requires judgment (that is, it discards most of the data)
- Regression analysis, based on statistical estimation, can provide more accurate estimates of cost; regression up next...

Regression Analysis

Regression analysis is a *statistical method* for obtaining the unique cost-estimating equation by minimizing, for a set of data points, the sum of the squares of the estimation errors:

- An *error* is the distance measured from the regression line to the data point
- Appropriately, this method of cost-estimation is referred to as *least-squares regression*

Regression Analysis (continued)

Regression analysis involves two types of variables:

- The *dependent variable* is the cost to be estimated
- The *independent variable* is the cost driver(s) used to estimate cost:
 - When one cost driver is used, the regression model is referred to as a *simple regression* model
 - When two or more cost drivers are used, the regression model is referred to as a *multiple regression* model

Learning curves

A learning curve is a function that shows how labour-hours per unit decline as units of output increase.

Experience curve

Experience curve is a function that shows how the costs per unit in various value chain areas decline as units produced and sold increase.

Cumulative average-time learning model

Cumulative average time per unit is reduced by a constant percentage each time the cumulative quantity of units produced is doubled.

Cumulative average-time learning model (Continued)

The time needed to produce the last unit is reduced by a constant percentage each time the cumulative quantity of units produced is doubled.

What is a Learning Curve?

A **learning curve** is

- the rate at which labor hours per unit decrease as the volume of activity increases
- the relationship between cumulative average hours per unit and the cumulative number of units produced.

A learning curve can be represented mathematically as:

$$Y = \alpha X^r, \text{ where}$$

Y = cumulative average labor hours,

α = time required for the first unit,

X = cumulative number of units produced,

r = an index for learning = $\ln(\% \text{ learning})/\ln(2)$, and

$\ln$ is the natural logarithmic function.

Learning Curve Analysis (continued)

Below is the general equation used in learning-curve analysis:

$$Y = aX^b$$

Where:

- Y = the average time per unit of output
- a = the time required for the first unit of output
- X = cumulative output
- b = the learning index

Learning Curve Analysis

- A cost whose amount is influenced by learning is an example of nonlinear cost behavior
- When an activity has a certain labor component and repetition of the same activity or operation makes the labor more proficient, the task *over time* is completed more quickly with the same or higher level of quality

Learning Curve Analysis (continued)

***Learning curve analysis* is a systematic method for estimating costs when learning is present:**

- The *learning rate*, obtained by reviewing historical data, is the percentage by which average time (or total time) falls from previous levels as output doubles
- A learning rate ranges from one (no learning) to 0.5 (best possible; note, however, that a learning rate of 0.5 is not achievable in practice—it implies infinite learning wherein the total time for all units equals the time for the first unit)

Learning Curve Example

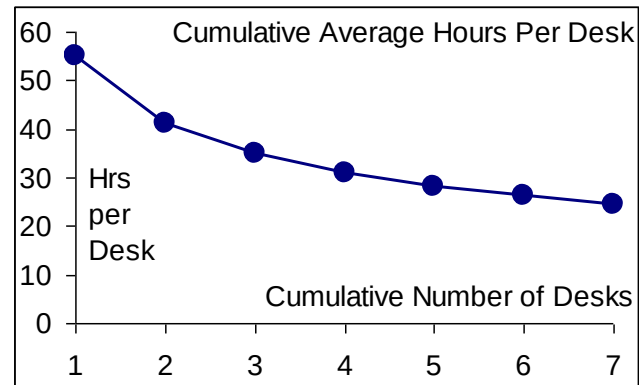
Deanna's Designer Desks just designed a new solid wood desk for executives. The first desk took her workforce 55 labor hours to make, but she estimates that each desk will require 75% of the time of the prior desk (i.e. “% learning” = 75%). Compute the cumulative average time to make 7 desks, and draw a learning curve.

First compute r : $r = \ln(75\%)/\ln(2) = -0.2877/0.693 = -0.4152$

Then compute the cumulative average time for 7 desks:

$$Y = 55 \times 7^{(-0.4152)} = 25.42 \text{ hrs}$$

In order to draw a learning curve, you must compute the value of Y for all X values from 1 to 7. . . .



Learning Curve Analysis (continued)

- Learning curve analysis is useful in: life-cycle planning, cost-volume-profit analysis, budgeting production levels and labor needs, make-or-buy decisions, preparing bids for production contracts, developing standard product costs, management control, and capital budgeting, among other applications...
- Y/a is the *learning rate*; for a learning rate of 80% and with the common assumption that that learning rate applies when output doubles, the learning index is $b = -0.3219$

Learning Curve Analysis (continued)

Learning curve analysis has three inherent limitations:

- ❶ The approach is for labor-intensive contexts that involve repetitive tasks such as long production runs or repetitive operations, and this is becoming less common in organizations of all types
- ❷ The learning rate is assumed to be constant
- ❸ A carefully estimated learning curve might be unreliable because the observed change in productivity in the data used to fit the model was actually associated with factors other than learning

Types of Learning Curves

- Cumulative average-time learning model—cumulative *average time per unit* declines by a constant percentage each time the cumulative quantity of units produced doubles.
- Incremental unit-time learning model—incremental *time needed to produce the last unit declines* by a constant percentage each time the cumulative quantity of units produced doubles.

Sample Cumulative Average-Time Model

	A	B	C	D	E	F	G	H	I
1	Cumulative Average-Time Learning Model for Rayburn Corporation								
2									
3		80% Learning Curve							
4									
5	Cumulative	Cumulative		Cumulative	Individual Unit				
6	Number	Average Time		Total Time:	Time for X th				
7	of Units (X)	per Unit (y)*: Labor Hours		Labor-Hours	Unit: Labor Hours				
8									
9				D = Col A x Col B					
10									
11	1	100.00		100.00	100.00				
12	2	80.00	=(100x0.8)	160.00	60.00				
13	3	70.21		210.63	50.63				
14	4	64.00	=(80x0.8)	256.00	45.37				
15	5	59.56		297.82	41.82				
16	6	56.17		337.01	39.19				
17	7	53.45		374.14	37.13				
18	8	51.20	=(64x0.8)	409.60	35.46				
19	9	49.29		443.65	34.05				
20	10	47.65		476.51	32.86				
21	11	46.21		508.32	31.81				
22	12	44.93		539.22	30.89				
23	13	43.79		569.29	30.07				
24	14	42.76		598.63	29.34				
25	15	41.82		627.30	28.67				
26	16	40.96	=(51.2x0.8)	655.36	28.06				
27									

E13 = D13 - D12
 = 210.63 - 160.00

*The mathematical relationship underlying the cumulative average-time learning model is:

$$y = aX^b$$

where y = Cumulative average time (labor-hours) per unit
 X = Cumulative number of units produced
 a = Time (labor-hours) required to produce the first unit
 b = Factor used to calculate cumulative average time to produce units

The value of b is calculated as

$$\frac{\ln(\text{learning-curve \% in decimal form})}{\ln 2}$$

For an 80% learning curve, $b = \ln 0.8 / \ln 2 = -0.2231 / 0.6931 = -0.3219$
 when $X = 3$, $a = 100$, $b = -0.3219$,
 $y = 100 \times 3^{-0.3219} = 70.21$ labor hours

Numbers in table may not be exact because of rounding.

Sample Incremental Unit-Time learning Model

	A	B	C	D	E	F	G	H	I
1	Incremental Unit-Time Learning Model for Rayburn Corporation								
2									
3		80% Learning Curve							
4									
5	Cumulative	Individual Unit Time		Cumulative	Cumulative				
6	Number	for Xth Unit (y)*:		Total Time:	Average Time				
7	of Units (X)	Labor Hours		Labor-Hours	per Unit:				
8					Labor-Hours				
9									
10					E = Col D ÷ Col A				
11									
12	1	100.00		100.00	100.00				
13	2	80.00	=(100x0.8)	180.00	90.00				
14	3	70.21		250.21	83.40				
15	4	64.00	=(80x0.8)	314.21	78.55				
16	5	59.56		373.77	74.75				
17	6	56.17		429.94	71.66				
18	7	53.45		483.39	69.06				
19	8	51.20	=(64x0.8)	534.59	66.82				
20	9	49.29		583.89	64.88				
21	10	47.65		631.54	63.15				
22	11	46.21		677.75	61.61				
23	12	44.93		722.68	60.22				
24	13	43.79		766.47	58.96				
25	14	42.76		809.23	57.80				
26	15	41.82		851.05	56.74				
27	16	40.96	=(51.2x0.8)	892.01	55.75				
28									

$$D14 = D13 + B14$$

$$= 180.00 + 70.21$$

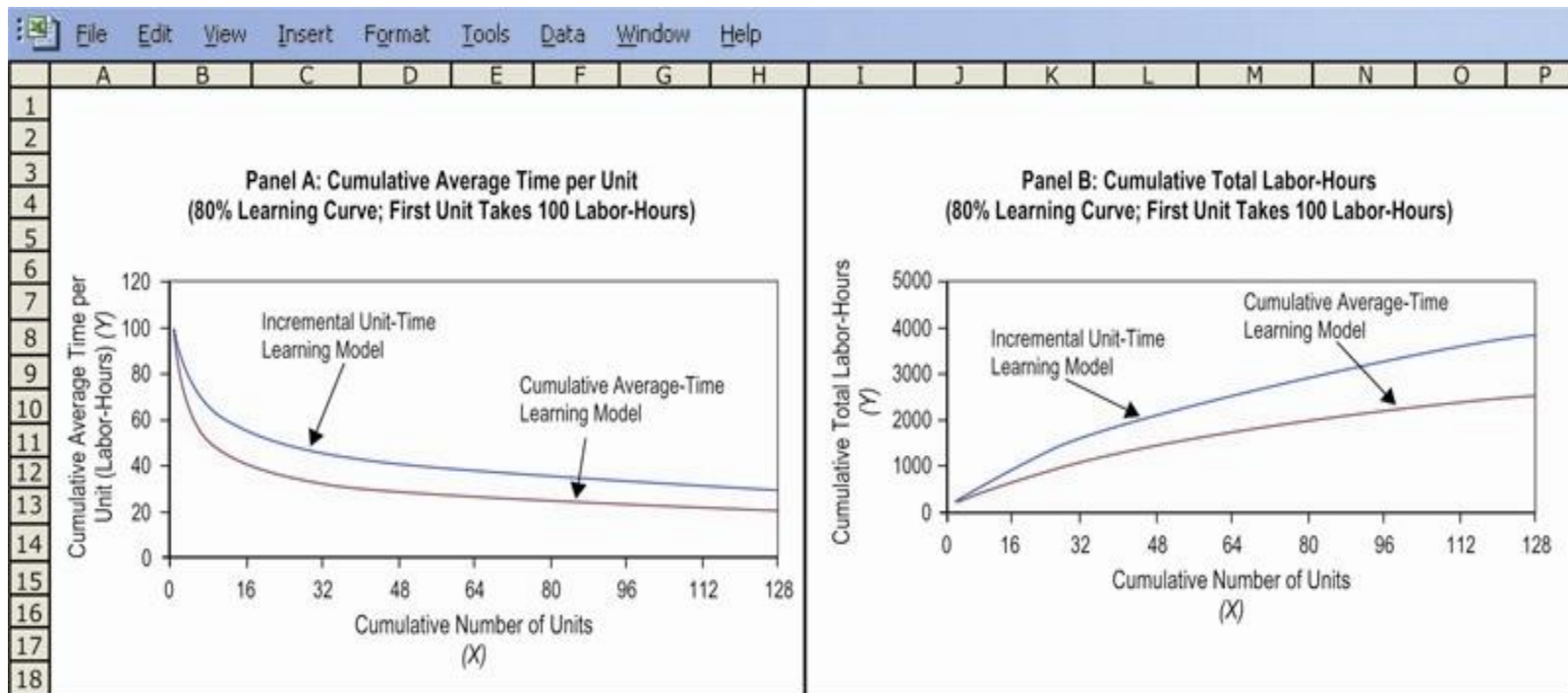
*The mathematical relationship underlying the incremental unit-time learning model is:

$$y = aX^b$$

where y = Time (labor-hours) taken to produce the last single unit
 X = Cumulative number of units produced
 a = Time (labor-hours) required to produce the first unit
 b = Factor used to calculate incremental unit time to produce units
 $= \frac{\ln(\text{learning-curve \% in decimal form})}{\ln 2}$

For an 80% learning curve, $b = \ln 0.8 \div \ln 2 = -0.2231 \div 0.6931 = -0.3219$
 Where $X = 3$, $a = 100$, $b = -0.3219$,
 $y = 100 \times 3^{-0.3219} = 70.21$ labor hours
 The cumulative total time when $X = 3$ is $100 + 80 + 70.21 = 250.21$ labor-hours.
 Numbers in the table may not be exact because of rounding.

Time Learning Model Comparative Plots



Predicting Costs Using Alternative Time Learning Models

	A	B	C	D	E	F
1		Cumulative				
2	Cumulative	Average Time	Cumulative	Cumulative Costs		Additions to
3	Number of	per Unit:	Total Time:	at \$50 per		Cumulative
4	Units	Labor-Hours^a	Labor-Hours^a	Labor-Hour		Costs
5	1	100.00	100.00	\$ 5,000	(100.00 x \$50)	\$ 5,000
6	2	80.00	160.00	8,000	(160.00 x \$50)	3,000
7	4	64.00	256.00	12,800	(256.00 x \$50)	4,800
8	8	51.20	409.60	20,480	(409.60 x \$50)	7,680
9	16	40.96	655.36	32,768	(655.36 x \$50)	12,288
10						
11	^a Based on the cumulative average-time learning model. See Exhibit 10-10 for the computations					
12	of these amounts.					

Data collection and adjustment issues

The ideal database has two characteristics:

1. The database should contain numerous reliably measured observations of the cost driver and the related costs.
2. The database should consider many values spanning a wide range for the cost driver.

Data Problems

1. The time period for measuring the dependent variable does not properly match the period for measuring the cost driver.
2. Fixed costs are allocated as if they are variable.
3. Data are either not available for all observations or are not uniformly reliable.

Data Problems, cont'd

4. Extreme values of observations occur.
5. There is no homogeneous relationship between the cost driver and the individual cost items in the dependent variable-cost pool. (A homogeneous relationship exists when each activity whose costs are included in the dependent variable has the same cost driver.)

Data Problems, concluded

6. The relationship between the cost driver and the cost is not stationary. This can occur when the underlying process that generated the observations has not remained stable over time.
7. Inflation has affected the costs, the cost driver, or both.