## Sharp Printing, AG

Three years ago the Sharp Printing (SP) strategic management group set a goal of having a color laser printer available for the consumer and small business market for less than $200. A few months later the senior management met off-site to discuss the new product. The results of this meeting were a set of general technical specifications along with major deliverables, a product launch date, and a cost estimate based on prior experience.

Shortly afterward, a meeting was arranged for middle management explaining the project goals, major responsibilities, the project start date, and importance of meeting the product launch date within the cost estimate. Members of all departments involved attended the meeting. Excitement was high. Although everyone saw the risks as high, the promised rewards for the company and the personnel were emblazoned in their minds. A few participants questioned the legitimacy of the project duration and cost estimates. A couple of R&D people were worried about the technology required to produce the high-quality product for less than $200. But given the excitement of the moment, everyone agreed the project was worth doing and doable. The color laser printer project was to have the highest project priority in the company.

Lauren was selected to be the project manager. She had 15 years of experience in printer design and manufacture, which included successful management of several projects related to printers for commercial markets. Since she was one of those uncomfortable with the project cost and time estimates, she felt getting good bottom-up time and cost estimates for the deliverables was her first concern. She quickly had a meeting with the significant stakeholders to create a WBS identifying the work packages and organizational unit responsible for implementing the work packages. Lauren stressed she wanted time and cost estimates from those who would do the work or were the most knowledgeable, if possible. Getting estimates from more than one source was encouraged. Estimates were due in two weeks.

The compiled estimates were placed in the WBS/OBS. The corresponding cost estimate seemed to be in error. The cost estimate was $1,250,000 over the senior management estimate; this represents about a 20 percent overrun! The time estimate from the developed project network was only four months over the top management time estimate. Another meeting was scheduled with the significant stakeholders to check the estimates and to brainstorm for alternative solutions; the cost and time estimates appeared to be reasonable. Some of the suggestions for the brainstorming session are listed below.

- Change scope.
- Outsource technology design.
- Use the priority matrix (found in Chapter 4) to get top management to clarify their priorities.
- Partner with another organization or build a research consortium to share costs and to share the newly developed technology and production methods.
- Cancel the project.
- Commission a break-even study for the laser printer.

Very little in the way of concrete savings was identified, although there was consensus that time could be compressed to the market launch date, but at additional costs.

Lauren met with the marketing (Connor), production (Kim), and design (Gage) managers who yielded some ideas for cutting costs, but nothing significant enough to have a large impact. Gage remarked, “I wouldn’t want to be the one to deliver

the message to top management that their cost estimate is $1,250,000 off! Good luck, Lauren."

1. At this point, what would you do if you were the project manager?
2. Was top management acting correctly in developing an estimate?
3. What estimating techniques should be used for a mission critical project such as this?

# Appendix 5.1

## Learning Curves for Estimating

A forecast estimate of the time required to perform a work package or task is a basic necessity for scheduling the project. In some cases, the manager simply uses judgment and past experience to estimate work package time, or may use historical records of similar tasks.

Most managers and workers intuitively know that improvement in the amount of time required to perform a task or group of tasks occurs with repetition. A worker can perform a task better/quicker the second time and each succeeding time she/he performs it (without any technological change). It is this pattern of improvement that is important to the project manager and project scheduler.

This improvement from repetition generally results in a reduction of labor hours for the accomplishment of tasks and results in lower project costs. From empirical evidence across *all* industries, the pattern of this improvement has been quantified in the *learning curve* (also known as improvement curve, experience curve, and industrial progress curve), which is described by the following relationship:

*Each time the output quantity doubles, the unit labor hours are reduced at a constant rate.*

For example, assume that a manufacturer has a new contract for 16 prototype units and a total of 800 labor hours were required for the first unit. Past experience has indicated that on similar types of units the improvement rate was 80 percent. This relationship of improvement in labor hours is shown below:

| Unit | | Labor Hours |
|---|---|---|
| 1 | | 800 |
| 2 | 800 × .80 = | 640 |
| 4 | 640 × .80 = | 512 |
| 8 | 512 × .80 = | 410 |
| 16 | 410 × .80 = | 328 |

By using Table A5.1 unit values, similar labor hours per unit can be determined. Looking across the 16 unit level and down the 80 percent column, we find a ratio of .4096. By multiplying this ratio times the labor hours for the first unit, we obtained the per unit value:

$$.4096 \times 800 = 328 \text{ hours or } 327.68$$

**TABLE A5.1**
**Learning Curves**
**Unit Values**

| Units | 60% | 65% | 70% | 75% | 80% | 85% | 90% | 95% |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| 2 | .6000 | .6500 | .7000 | .7500 | .8000 | .8500 | .9000 | .9500 |
| 3 | .4450 | .5052 | .5682 | .6338 | .7021 | .7729 | .8462 | .9219 |
| 4 | .3600 | .4225 | .4900 | .5625 | .6400 | .7225 | .8100 | .9025 |
| 5 | .3054 | .3678 | .4368 | .5127 | .5956 | .6857 | .7830 | .8877 |
| 6 | .2670 | .3284 | .3977 | .4754 | .5617 | .6570 | .7616 | .8758 |
| 7 | .2383 | .2984 | .3674 | .4459 | .5345 | .6337 | .7439 | .8659 |
| 8 | .2160 | .2746 | .3430 | .4219 | .5120 | .6141 | .7290 | .8574 |
| 9 | .1980 | .2552 | .3228 | .4017 | .4930 | .5974 | .7161 | .8499 |
| 10 | .1832 | .2391 | .3058 | .3846 | .4765 | .5828 | .7047 | .8433 |
| 12 | .1602 | .2135 | .2784 | .3565 | .4493 | .5584 | .6854 | .8320 |
| 14 | .1430 | .1940 | .2572 | .3344 | .4276 | .5386 | .6696 | .8226 |
| 16 | .1296 | .1785 | .2401 | .3164 | .4096 | .5220 | .6561 | .8145 |
| 18 | .1188 | .1659 | .2260 | .3013 | .3944 | .5078 | .6445 | .8074 |
| 20 | .1099 | .1554 | .2141 | .2884 | .3812 | .4954 | .6342 | .8012 |
| 22 | .1025 | .1465 | .2038 | .2772 | .3697 | .4844 | .6251 | .7955 |
| 24 | .0961 | .1387 | .1949 | .2674 | .3595 | .4747 | .6169 | .7904 |
| 25 | .0933 | .1353 | .1908 | .2629 | .3548 | .4701 | .6131 | .7880 |
| 30 | .0815 | .1208 | .1737 | .2437 | .3346 | .4505 | .5963 | .7775 |
| 35 | .0728 | .1097 | .1605 | .2286 | .3184 | .4345 | .5825 | .7687 |
| 40 | .0660 | .1010 | .1498 | .2163 | .3050 | .4211 | .5708 | .7611 |
| 45 | .0605 | .0939 | .1410 | .2060 | .2936 | .4096 | .5607 | .7545 |
| 50 | .0560 | .0879 | .1336 | .1972 | .2838 | .3996 | .5518 | .7486 |
| 60 | .0489 | .0785 | .1216 | .1828 | .2676 | .3829 | .5367 | .7386 |
| 70 | .0437 | .0713 | .1123 | .1715 | .2547 | .3693 | .5243 | .7302 |
| 80 | .0396 | .0657 | .1049 | .1622 | .2440 | .3579 | .5137 | .7231 |
| 90 | .0363 | .0610 | .0987 | .1545 | .2349 | .3482 | .5046 | .7168 |
| 100 | .0336 | .0572 | .0935 | .1479 | .2271 | .3397 | .4966 | .7112 |
| 120 | .0294 | .0510 | .0851 | .1371 | .2141 | .3255 | .4830 | .7017 |
| 140 | .0262 | .0464 | .0786 | .1287 | .2038 | .3139 | .4718 | .6937 |
| 160 | .0237 | .0427 | .0734 | .1217 | .1952 | .3042 | .4623 | .6869 |
| 180 | .0218 | .0397 | .0691 | .1159 | .1879 | .2959 | .4541 | .6809 |
| 200 | .0201 | .0371 | .0655 | .1109 | .1816 | .2887 | .4469 | .6757 |
| 250 | .0171 | .0323 | .0584 | .1011 | .1691 | .2740 | .4320 | .6646 |
| 300 | .0149 | .0289 | .0531 | .0937 | .1594 | .2625 | .4202 | .5557 |
| 350 | .0133 | .0262 | .0491 | .0879 | .1517 | .2532 | .4105 | .6482 |
| 400 | .0121 | .0241 | .0458 | .0832 | .1453 | .2454 | .4022 | .6419 |
| 450 | .0111 | .0224 | .0431 | .0792 | .1399 | .2387 | .3951 | .6363 |
| 500 | .0103 | .0210 | .0408 | .0758 | .1352 | .2329 | .3888 | .6314 |
| 600 | .0090 | .0188 | .0372 | .0703 | .1275 | .2232 | .3782 | .6229 |
| 700 | .0080 | .0171 | .0344 | .0659 | .1214 | .2152 | .3694 | .6158 |
| 800 | .0073 | .0157 | .0321 | .0624 | .1163 | .2086 | .3620 | .6098 |
| 900 | .0067 | .0146 | .0302 | .0594 | .1119 | .2029 | .3556 | .6045 |
| 1,000 | .0062 | .0137 | .0286 | .0569 | .1082 | .1980 | .3499 | .5998 |
| 1,200 | .0054 | .0122 | .0260 | .0527 | .1020 | .1897 | .3404 | .5918 |
| 1,400 | .0048 | .0111 | .0240 | .0495 | .0971 | .1830 | .3325 | .5850 |
| 1,600 | .0044 | .0102 | .0225 | .0468 | .0930 | .1773 | .3258 | .5793 |
| 1,800 | .0040 | .0095 | .0211 | .0446 | .0895 | .1725 | .3200 | .5743 |
| 2,000 | .0037 | .0089 | .0200 | .0427 | .0866 | .1683 | .3149 | .5698 |
| 2,500 | .0031 | .0077 | .0178 | .0389 | .0606 | .1597 | .3044 | .5605 |
| 3,000 | .0027 | .0069 | .0162 | .0360 | .0760 | .1530 | .2961 | .5530 |

That is, the 16th unit should require close to 328 labor hours, assuming an 80 percent improvement ratio.

Obviously, a project manager may need more than a single unit value for estimating the time for some work packages. The cumulative values in Table A5.2 provide factors for computing the cumulative total labor hours of all units. In the previous example, for the first 16 units, the total labor hours required would be

$$800 \times 8.920 = 7{,}136 \text{ hours}$$

By dividing the total cumulative hours (7,136) by the units, the average unit labor hours can be obtained:

$$7{,}136 \text{ labor hours}/16 \text{ units} = 446 \text{ average labor hours per unit}$$

Note how the labor hours for the 16th unit (328) differs from the average for all 16 units (446). The project manager, knowing the average labor costs and processing costs, could estimate the total prototype costs. (The mathematical derivation of factors found in Tables A5.1 and A5.2 can be found in Jelen, F. C. and J. H. Black, *Cost and Optimization Engineering,* 2nd ed. (New York: McGraw-Hill, 1983.)

## FOLLOW-ON CONTRACT EXAMPLE

Assume the project manager gets a follow-on order of 74 units; how should she estimate labor hours and cost? Going to the cumulative Table A5.2 we find at the 80 percent ratio and 90 total units intersection—a 30.35 ratio.

| | |
|---|---|
| $800 \times 30.35 =$ | 24,280 labor hours for 90 units |
| Less previous 16 units = | 7,136 |
| Total follow-on order = | 17,144 labor hours |
| 17,144/74 equals 232 average labor hours per unit | |

Labor hours for the 90th unit can be obtained from Table A5.1: $.2349 \times 800 =$ 187.9 labor hours. (For ratios between given values, simply estimate.)

### Exercise A5.1

**Norwegian Satellite Development Company**
**Cost Estimates**
**for**
**World Satellite Telephone Exchange Project**

NSDC has a contract to produce eight satellites to support a worldwide telephone system (for Alaska Telecom, Inc.) that allows individuals to use a single, portable telephone in any location on earth to call in and out. NSDC will develop and produce the eight units. NSDC has estimated that the R&D costs will be NOK (Norwegian Krone) 12,000,000. Material costs are expected to be NOK 6,000,000. They have estimated the design and production of the first satellite will require 100,000 labor hours and an 80 percent improvement curve is expected.

**TABLE A5.2**
**Learning Curves**
**Cumulative Values**

| Units | 60% | 65% | 70% | 75% | 80% | 85% | 90% | 95% |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| 2 | 1.600 | 1.650 | 1.700 | 1.750 | 1.800 | 1.850 | 1.900 | 1.950 |
| 3 | 2.045 | 2.155 | 2.268 | 2.384 | 2.502 | 2.623 | 2.746 | 2.872 |
| 4 | 2.405 | 2.578 | 2.758 | 2.946 | 3.142 | 3.345 | 3.556 | 3.774 |
| 5 | 2.710 | 2.946 | 3.195 | 3.459 | 3.738 | 4.031 | 4.339 | 4.662 |
| 6 | 2.977 | 3.274 | 3.593 | 3.934 | 4.299 | 4.688 | 5.101 | 5.538 |
| 7 | 3.216 | 3.572 | 3.960 | 4.380 | 4.834 | 5.322 | 5.845 | 6.404 |
| 8 | 3.432 | 3.847 | 4.303 | 4.802 | 5.346 | 5.936 | 6.574 | 7.261 |
| 9 | 3.630 | 4.102 | 4.626 | 5.204 | 5.839 | 6.533 | 7.290 | 8.111 |
| 10 | 3.813 | 4.341 | 4.931 | 5.589 | 6.315 | 7.116 | 7.994 | 8.955 |
| 12 | 4.144 | 4.780 | 5.501 | 6.315 | 7.227 | 8.244 | 9.374 | 10.62 |
| 14 | 4.438 | 5.177 | 6.026 | 6.994 | 8.092 | 9.331 | 10.72 | 12.27 |
| 16 | 4.704 | 5.541 | 6.514 | 7.635 | 8.920 | 10.38 | 12.04 | 13.91 |
| 18 | 4.946 | 5.879 | 6.972 | 8.245 | 9.716 | 11.41 | 13.33 | 15.52 |
| 20 | 5.171 | 6.195 | 7.407 | 8.828 | 10.48 | 12.40 | 14.64 | 17.13 |
| 22 | 5.379 | 6.492 | 7.819 | 9.388 | 11.23 | 13.38 | 15.86 | 18.72 |
| 24 | 5.574 | 6.773 | 8.213 | 9.928 | 11.95 | 14.33 | 17.10 | 20.31 |
| 25 | 5.668 | 6.909 | 8.404 | 10.19 | 12.31 | 14.80 | 17.71 | 21.10 |
| 30 | 6.097 | 7.540 | 9.305 | 11.45 | 14.02 | 17.09 | 20.73 | 25.00 |
| 35 | 6.478 | 8.109 | 10.13 | 12.72 | 15.64 | 19.29 | 23.67 | 28.86 |
| 40 | 6.821 | 8.631 | 10.90 | 13.72 | 17.19 | 21.43 | 26.54 | 32.68 |
| 45 | 7.134 | 9.114 | 11.62 | 14.77 | 18.68 | 23.50 | 29.37 | 36.47 |
| 50 | 7.422 | 9.565 | 12.31 | 15.78 | 20.12 | 25.51 | 32.14 | 40.22 |
| 60 | 7.941 | 10.39 | 13.57 | 17.67 | 22.87 | 29.41 | 37.57 | 47.65 |
| 70 | 8.401 | 11.13 | 14.74 | 19.43 | 25.47 | 33.17 | 42.87 | 54.99 |
| 80 | 8.814 | 11.82 | 15.82 | 21.09 | 27.96 | 36.80 | 48.05 | 62.25 |
| 90 | 9.191 | 12.45 | 16.83 | 22.67 | 30.35 | 40.32 | 53.14 | 69.45 |
| 100 | 9.539 | 13.03 | 17.79 | 24.18 | 32.65 | 43.75 | 58.14 | 76.59 |
| 120 | 10.16 | 14.16 | 19.57 | 27.02 | 37.05 | 50.39 | 67.93 | 90.71 |
| 140 | 10.72 | 15.08 | 21.20 | 29.67 | 41.22 | 56.78 | 77.46 | 104.7 |
| 160 | 11.21 | 15.97 | 22.72 | 32.17 | 45.20 | 62.95 | 86.80 | 118.5 |
| 180 | 11.67 | 16.79 | 24.14 | 34.54 | 49.03 | 68.95 | 95.96 | 132.1 |
| 200 | 12.09 | 17.55 | 25.48 | 36.80 | 52.72 | 74.79 | 105.0 | 145.7 |
| 250 | 13.01 | 19.28 | 28.56 | 42.08 | 61.47 | 88.83 | 126.9 | 179.2 |
| 300 | 13.81 | 20.81 | 31.34 | 46.94 | 69.66 | 102.2 | 148.2 | 212.2 |
| 350 | 14.51 | 22.18 | 33.89 | 51.48 | 77.43 | 115.1 | 169.0 | 244.8 |
| 400 | 15.14 | 23.44 | 36.26 | 55.75 | 84.85 | 127.6 | 189.3 | 277.0 |
| 450 | 15.72 | 24.60 | 38.48 | 59.80 | 91.97 | 139.7 | 209.2 | 309.0 |
| 500 | 16.26 | 25.68 | 40.58 | 63.68 | 98.85 | 151.5 | 228.8 | 340.6 |
| 600 | 17.21 | 27.67 | 44.47 | 70.97 | 112.0 | 174.2 | 267.1 | 403.3 |
| 700 | 18.06 | 29.45 | 48.04 | 77.77 | 124.4 | 196.1 | 304.5 | 465.3 |
| 800 | 18.82 | 31.09 | 51.36 | 84.18 | 136.3 | 217.3 | 341.0 | 526.5 |
| 900 | 19.51 | 32.60 | 54.46 | 90.26 | 147.7 | 237.9 | 376.9 | 587.2 |
| 1,000 | 20.15 | 34.01 | 57.40 | 96.07 | 158.7 | 257.9 | 412.2 | 647.4 |
| 1,200 | 21.30 | 36.59 | 62.85 | 107.0 | 179.7 | 296.6 | 481.2 | 766.6 |
| 1,400 | 22.32 | 38.92 | 67.85 | 117.2 | 199.6 | 333.9 | 548.4 | 884.2 |
| 1,600 | 23.23 | 41.04 | 72.49 | 126.8 | 218.6 | 369.9 | 614.2 | 1001. |
| 1,800 | 24.06 | 43.00 | 76.85 | 135.9 | 236.8 | 404.9 | 678.8 | 1116. |
| 2,000 | 24.83 | 44.84 | 80.96 | 144.7 | 254.4 | 438.9 | 742.3 | 1230. |
| 2,500 | 26.53 | 48.97 | 90.39 | 165.0 | 296.1 | 520.8 | 897.0 | 1513. |
| 3,000 | 27.99 | 52.62 | 98.90 | 183.7 | 335.2 | 598.9 | 1047. | 1791. |

Skilled labor cost is NOK 300 per hour. Desired profit for all projects is 25 percent of total costs.

A. How many labor hours should the eighth satellite require?
B. How many labor hours for the whole project of eight satellites?
C. What price would you ask for the project? Why?
D. Midway through the project your design and production people realize that a 75 percent improvement curve is more appropriate. What impact does this have on the project?
E. Near the end of the project Deutsch Telefon AG has requested a cost estimate for four satellites identical to those you have already produced. What price will you quote them? Justify your price.