SUPPLEMENT 10

Work Measurement

DISCUSSION QUESTIONS

1. Labor standards are set in four ways: historical experience, time studies, predetermined time standards, and work sampling.

2. Normal time adjusts the observed time to what a normal worker could be expected to accomplish by multiplying the average observed cycle time by a performance rating factor.

3. Labor standards are used to:

1. Determine labor content of items produced
2. Determine staffing needs of organizations
3. Determine cost and time estimates prior to production
4. Determine crew size and work balance
5. Determine production expected
6. Determine the basis of wage-incentive plans
7. Determine efficiency of employees and supervision

4. The observations should be handled as follows:

(a) An extra long look: judgment as to quality: include in the standard
(b) Imperfection causing difficulty in fitting the piece into the jig: include in the standard
(c) Change tool: include in the standard

5. *Standard time is normal time* that has been adjusted for appropriate allowances.

6. Not all employees respond the same way, but one would usually expect an employee to work somewhat slower than normal while being observed. The employee perceives that the faster he or she works during evaluation, the higher the normal rate will be set. Conversely, other employees take pride in superior performance and work faster than a normal pace.

7. Classify as follows:

a) The operator stops to talk to you: do not include (delay)
b) The operator lights up a cigarette: do not include (personal)
c) Operator opens lunch pail: do not include (personal)

8. Waiting time: waiting time is included in an allowance as delay.

9. Material movement or replenishment: include in the standard unless a separate materials handling group exists.

10. Operator drops a part, you pick it up and hand it to him: do not include. Outside help or interference distorts the results of the study.

11. *Gilbreth's approach* to setting work standards is to divide manual work into small basic elements that already have established time. Units of time are very small (0.0006 minutes) and are called Therbligs.

ACTIVE MODEL EXERCISE

ACTIVE MODEL S10.1: Work Sampling

1. Scroll over the graph to determine what the sample size should be if $p = 30\%$.

933

2. Based on the graph, what value of p requires the largest sample size?

0.5

3. Use the scrollbar to determine what happens to the sample size as the number of standard deviations, z, increases?

The sample size increases.

4. Use the scrollbar to determine what happens to the sample size as the acceptable error, h, increases?

The sample size decreases.

END-OF-SUPPLEMENT PROBLEMS

S10.1 The next step should probably be to take another set of observations. The time of 56 seconds would appear to be an outlier and should be investigated further. It may represent the impact of a problem with the process, or with inferior raw materials, or an error in data collection.

S10.2 NT = Avg × PR = 8.5 × 1.10 = 9.35 seconds; worker is faster than normal

S10.3 NT = Avg × PR = 8.5 × 0.90 = 7.65 seconds; worker is slower than normal

S10.4 (a) $ST = \dfrac{NT}{1-AF} = \dfrac{9.35}{1-0.15} = 11$ seconds

(b) $ST = \dfrac{NT}{1-AF} = \dfrac{7.65}{1-0.18} = 9.33$ seconds

S10.5 (a) $\text{Average time} = \dfrac{\text{Sum of times}}{\text{Number of cycles}} = \dfrac{1.74}{16}$

$= 0.10875 \text{ minutes} = 6.525 \text{ seconds}$

(b) $\text{Normal time} = (\text{Average time}) \times (\text{Performance rating factor})$

$= 6.525 \times 95\% = 6.2 \text{ seconds}$

(c) $\text{Standard time} = \dfrac{\text{Normal time}}{1 - \text{Allowance factor}}$

$= \dfrac{6.2}{1-8\%} = \dfrac{6.2}{92\%} = 6.739 \text{ seconds}$

S10.6 NT = Cycle time × PR = (50) × (1.10) = 55 seconds

S10.7 (a) Normal time = 12 minutes × 1.05 = 12.6 minutes

(b) $$\text{Standard time} = \frac{\text{Normal time}}{1 - \text{Allowance factor}}$$
$$= \frac{12.6}{1 - 0.16} = 15 \text{ minutes}$$

S10.8 $$\text{Avg} = \frac{2.2 + 2.6 + 2.3 + 2.5 + 2.4}{5} = 2.4 \text{ minutes}$$

$NT = 2.4 \times 1.05 = 2.52$

$$ST = \frac{2.52}{1 - 0.10} = 2.8 \text{ minutes}$$

S10.9 (a) Normal time = 12 seconds × 1.00 = 12.0 seconds

(b) $$\text{Standard time} = \frac{\text{Normal time}}{1 - \text{Allowance factor}}$$
$$= \frac{12.0}{1 - 0.15} = 14.12 \text{ seconds}$$

S10.10 Normal time = 5.3 minutes × 1.05 = 5.565 minutes

$$\text{Allowance Fraction} = \frac{\text{Personal} + \text{Fatigue} + \text{Delay}}{60 \text{ minutes}}$$
$$= \frac{3 + 2 + 1}{60} = \frac{6}{60} = 0.10$$

$$\text{Standard time} = \frac{\text{Normal time}}{1 - \text{Allowance factor}}$$
$$= \frac{5.565}{1 - 0.10} = 6.183 \text{ minutes}$$

S10.11 Normal time = 25 minutes

Allowances = 5 + 10 + 2 = 17 min per hour

(a) $$\text{Allowance factor} = \frac{\text{Personal} + \text{Fatigue} + \text{Delay}}{60}$$
$$= \frac{5 + 10 + 2}{60} = \frac{17}{60} = .283$$

(b) $$\text{Standard time} = \frac{\text{Normal time}}{1 - \text{Allowance factor}} = \frac{25}{1 - \frac{17}{60}}$$
$$= \frac{25}{1 - .283} = 34.9 \text{ minutes}$$

S10.12

		Observation (minutes per cycle)						
Element	**Rating**	**1**	**2**	**3**	**4**	**5**	**Average Time**	**Normal Time**
1	100%	1.5	1.6	1.4	1.5	1.5	1.5	1.50
2	90%	2.3	2.5	2.1	2.2	2.4	2.3	2.07
3	120%	1.7	1.9	1.9	1.4	1.6	1.7	2.04
4	100%	3.5	3.6	3.6	3.6	3.2	3.5	3.50

Normal time for lab test = 9.11

$$\text{Standard time for lab test} = \frac{\text{Normal time for process}}{1 - \text{Allowance factor}} = \frac{9.11}{1 - 0.18} = 11.1 \text{ minutes}$$

S10.13

Element	Rating	Observation (minutes per cycle) 1	2	3	4	5	Average	Normal
Check mini-bar	100%	1.5	1.6	1.4	1.5	1.5	1.5	1.50
Make one bed	90%	2.3	2.5	2.1	2.2	2.4	2.3	2.07
Vacuum	120%	1.7	1.9	1.9	1.4	1.6	1.7	2.04
Clean bath	100%	3.5	3.6	3.6	3.6	3.2	3.5	3.50
								9.11

Normal time for process = 9.11

$$\text{Standard time for process} = \frac{\text{Normal time for process}}{1 - \text{Allowance factor}} = \frac{9.11}{1 - 0.10} = 10.12 \text{ minutes}$$

S10.14

Job Element	Observed Time (minutes)						Perf. Rating
Typing letter	2.5	3.5	2.8	2.1	2.6	3.3	85%
Typing envelope	0.8	0.8	0.6	0.8	3.1[a]	0.7	100%
Stuffing envelope	0.4	0.5	1.9[a]	0.3	0.6	0.5	95%
Sealing, sorting	1.0	2.9[b]	0.9	1.0	4.4[b]	0.9	125%

[a] Disregard—secretary stopped to answer the phone.
[b] Disregard—interuption by supervisor.

Calculating average cycle time:

$$\text{Element 1} = \frac{2.5 + 3.5 + 2.8 + 2.1 + 2.6 + 3.3}{6} = \frac{16.8}{6} = 2.8 \text{ minutes}$$

$$\text{Element 2} = \frac{0.8 + 0.8 + 0.6 + 0.8 + 0.7}{5} = \frac{3.7}{5} = 0.74 \text{ minutes}$$

$$\text{Element 3} = \frac{0.4 + 0.5 + 0.3 + 0.6 + 0.5}{5} = \frac{2.3}{5} = 0.46 \text{ minutes}$$

$$\text{Element 4} = \frac{1.0 + 0.9 + 1.0 + 0.9}{4} = \frac{3.8}{4} = 0.95 \text{ minutes}$$

Calculating normal time for each task element:
Normal time = Observed cycle time × Peformance rating
Element 1 = 2.80 × 0.85 = 2.38 minutes
Element 2 = 0.74 × 1.00 = 0.74 minutes
Element 3 = 0.46 × 0.95 = 0.44 minutes
Element 4 = 0.95 × 1.25 = 1.19 minutes

Normal time for the process:
Normal time for process = Sum of normal times for elements
= 2.38 + 0.74 + 0.44 + 1.19
= 4.75 minutes

Standard time for process:

$$\text{Standard time for process} = \frac{\text{Normal time for process}}{1 - \text{Allowance factor}}$$
$$= \frac{4.75}{1 - 0.12} = 5.40 \text{ minutes}$$

S10.15 Allowance = 23%

Job Element	Performance Rating	Observations (minutes) 1	2	3	4	5
1	97%	1.5	1.8	2.0	1.7	1.5
2	105%	0.6	0.4	0.7	3.7	0.5
3	86%	0.5	0.4	0.6	0.4	0.4
4	90%	0.6	0.8	0.7	0.6	0.7

The first thing to notice is that observation 4 of job element 2 is personal time and should be ignored.

(a) As shown below, normal time = 3.24 minutes.

Job Element	Performance Rating	Observations 1	2	3	4	5	Average Actual Time	Normal Time
1	97%	1.5	1.8	2.0	1.7	1.5	1.70	1.65
2	105%	0.6	0.4	0.7		0.5	0.55	0.58
3	86%	0.5	0.4	0.6	0.4	0.4	0.46	0.40
4	90%	0.6	0.8	0.7	0.6	0.7	0.68	0.61
								3.24

(b) Standard time $= \dfrac{\text{Normal time}}{1 - \text{Allowance}}$

Standard time $= \dfrac{3.24}{1-0.23} = \dfrac{3.24}{0.77} = 4.208$ minutes

S10.16 (a,b)

Task Element	Performance Rating	Observations (minutes) (actual time) 1	2	3	4	5	Solutions Actual Time Average	Normal Time
1	110%	0.5	0.4	0.6	0.4	0.4	0.46	0.506
2	95%	0.6	0.8	0.7	0.6	0.7	0.68	0.646
3	90%	0.6	0.4	0.7	0.5	0.5	0.54	0.486
4	85%	1.5	1.8	2.0	1.7	1.5	1.70	1.445
							Total	3.083

(a) Normal time = 3.083 minutes

(b) Standard time $= \dfrac{\text{Normal time}}{1 - \text{Total allowance}}$

$= \dfrac{3.083}{1.0 - 0.20} = 3.85$ minutes

S10.17 Initial sample: 3.5, 3.2, 4.1, 3.6, 3.9

$$\bar{x} = 3.5 + 3.2 + 4.1 + 3.6 + 3.9 = \frac{18.3}{5} = 3.66$$

$$s = \sqrt{\frac{\sum(\text{Sample observation} - \bar{x})^2}{\text{n} - 1}} = \sqrt{\frac{0.492}{5-1}} = \sqrt{0.123} = 0.35$$

$$n = \left(\frac{zs}{h\bar{x}}\right)^2 = \left(\frac{1.96 \times 0.35}{0.05 \times 3.66}\right)^2$$

$$= \left(\frac{.686}{.183}\right)^2 = 3.76^2 = 14.13, \text{ or 15 observations.}$$

S10.18 $n = \left(\dfrac{zs}{h\bar{x}}\right)^2 = \left(\dfrac{(2.58)(1.28)}{(0.05)(3.20)}\right)^2 = \left(\dfrac{3.30}{0.16}\right)^2 = 426$

where $z = 2.58,\ s = 1.28,\ h = 0.05,\ \bar{x} = 3.20$

Sample size 45 is not adequate. They need 381 more observations.

S10.19 (a) $n = \left(\dfrac{Zs}{h\bar{x}}\right)^2$ Thus, $Z = \dfrac{h\bar{x}\sqrt{n}}{s} = \dfrac{(0.10)(0.4)\left(\sqrt{12}\right)}{0.15}$

$= 0.924$

Referring to Appendix I (Standard Normal Table I.2), corresponding Area = 0.64 = 64%. The confidence level when $n = 12$ is 64%.

(b) Average observed time $= \dfrac{0.331 + 0.243 + \cdots + 0.484}{12}$

$= 0.4484$ minutes

Normal time = Average time × perf. rating

$= 0.4484 \times 0.90 = 0.4036$ minutes

Standard time $= \dfrac{\text{Normal time}}{1 - \text{Allowance factor}} = \dfrac{0.4036}{1 - 0.06}$

$= 0.429$ minutes

S10.20

Element	Observed Time (minutes)					Perf. Rating
Prepare daily reports	35	40	33	42	39	120%
Photocopy results	12	10	36[a]	15	13	110%
Label and package reports	3	3	5	5	4	90%
Distribute reports	15	18	21	17	45[b]	85%

[a] Photocopying machine broken (included in delay factor).
[b] Power outage (included in delay factor).

Calculating average observed time:

Element 1 $= \dfrac{35 + 40 + 33 + 42 + 39}{5} = \dfrac{189}{5} = 37.8$ minutes

Element 2 $= \dfrac{12 + 10 + 15 + 13}{4} = \dfrac{50}{4} = 12.5$ minutes

Element 3 $= \dfrac{3 + 3 + 5 + 5 + 4}{5} = \dfrac{20}{5} = 4.0$ minutes

Element 4 $= \dfrac{15 + 18 + 21 + 17}{4} = \dfrac{71}{4} = 17.75$ minutes

(a) *Calculating normal time for each task element:*

Normal time = Observed time × Performance rating

Element 1 = 37.80 × 1.20 = 45.36 minutes

Element 2 = 12.50 × 1.10 = 13.75 minutes

Element 3 = 4.00 × 0.90 = 3.6 minutes

Element 4 = 17.75 × 0.85 = 15.09 minutes

Normal time for the process:

Normal time for process = Sum of normal times for elements
= 45.36 + 13.75 + 3.6 + 15.09
= 77.8 minutes

(b) *Standard time for the process:*

$$\text{Standard time for process} = \frac{\text{Normal time for process}}{1 - \text{Allowance factor}}$$

$$= \frac{77.8}{1 - 0.15} = 91.53 \text{ minutes}$$

(c) *Sample size*:

From the equations relating to a normal distribution, we know that: $n = \left(\frac{zs}{h\bar{x}}\right)^2$, $h = 0.05$, $z = 1.96$.

Job Element	Mean Cycle Time	S^2	S	Sample*
Prepare daily reports	37.80	13.70	3.7	15
Photocopy results	12.50	4.33	2.1	44
Label and package reports	4.00	1.00	1.0	96**
Distribute reports	17.75	6.25	2.5	31

Sample size for the entire task must be at least 96 samples.

*All fractional sample sizes are rounded to the next highest integer value.

** $\left[\frac{(1.96)(1)}{(.05)(4)}\right]^2 = \left(\frac{1.96}{.2}\right)^2 = (9.8)^2 = 96$

S10.21 (a)

Job Element	Observed Time (seconds)					Perf. Rating
Grasp and place bag	8	9	8	11	7	110%
Fill bag	36	41	39	35	112[a]	85%
Seal bag	15	17	13	20	18	105%
Place bag on conveyor	8	6	9	30[b]	35[b]	90%

[a] Bag breaks open, include as part of delay in allowance factor.

[b] Conveyor jams, include as part of delay in allowance factor.

Note: If bags break open with any regularity, then these observations *would* be included in the time for this element . . . it would be part of the element and task.

Calculating average observed time:

$$\text{Element 1} = \frac{8 + 9 + 8 + 11 + 7}{5} = \frac{43}{5} = 8.6 \text{ seconds}$$

$$\text{Element 2} = \frac{36 + 41 + 39 + 35}{4} = \frac{151}{4} = 37.75 \text{ seconds}$$

$$\text{Element 3} = \frac{15 + 17 + 13 + 20 + 18}{5} = \frac{83}{5} = 16.6 \text{ seconds}$$

$$\text{Element 4} = \frac{8 + 6 + 9}{3} = \frac{23}{3} = 7.67 \text{ seconds}$$

Calculating normal time for each task element:

Normal time = Observed time × Performance rating

Element 1 = 8.60 × 1.10 = 9.46 seconds

Element 2 = 37.75 × 0.85 = 32.09 seconds

Element 3 = 16.60 × 1.05 = 17.43 seconds

Element 4 = 7.67 × 0.90 = 6.90 seconds

Normal time for the process:

Normal time for process = Sum of normal times for elements
= 9.46 + 32.09 + 17.43 + 6.90
= 65.88 seconds

Standard time for process:

$$\text{Standard time for process} = \frac{\text{Normal time for process}}{1 - \text{Allowance factor}}$$

$$= \frac{65.88}{1 - 0.23} = 85.56 \text{ seconds}$$

(b)

Job Element	Mean ($\bar{X}$)	Calculating Sample Size: Desired Accuracy (h)	Std. Dev. Required (Z)	Std. Dev. of Sample (S)	Samples Required
Grasp and place bag	8.60	0.05	2.58	1.52	83
Fill bag	37.75	0.05	2.58	2.75	14
Seal bag	16.60	0.05	2.58	2.70	70
Place bag on conveyor	7.67	0.05	2.58	1.54	107

$$n = \left(\frac{zs}{h\bar{x}}\right)^2 = \text{Sample size required}$$

$$n = \left(\frac{2.58 \times 1.52}{0.05 \times 8.6}\right)^2 = 83 \text{ samples for grasp and place bag}$$

$$n = \left(\frac{2.58 \times 2.75}{0.05 \times 37.75}\right)^2 = 14 \text{ samples for fill bag}$$

$$n = \left(\frac{2.58 \times 2.7}{0.05 \times 16.6}\right)^2 = 70 \text{ samples for seal bag}$$

$$n = \left(\frac{2.58 \times 1.54}{0.05 \times 7.67}\right)^2 = 107 \text{ samples for place bag on conveyor}$$

Therefore, if all cycles must be studied together (the typical case), 107 cycles must be studied.

S10.22 (a)

Job Element	Observed Time (minutes)							Performance Rating
Select correct muffler	4	5	4	6	4	15*	4	110%
Remove old muffler	6	8	7	6	7	6	7	90%
Weld/install new muffler	15	14	14	12	15	16	13	105%
Check/inspect work	3	4	24*	5	4	3	18*	100%
Complete paperwork	5	6	8	—	7	6	7	130%

*Employee stopped to talk to boss—exclude (personal time).

Calculating average observed time:

$$\text{Element 1} = \frac{4+5+4+6+4+4}{6} = \frac{27}{6} = 4.5 \text{ minutes}$$

$$\text{Element 2} = \frac{6+8+7+6+7+6+7}{7} = \frac{47}{7} = 6.71 \text{ minutes}$$

$$\text{Element 3} = \frac{15+14+14+12+15+16+13}{7} = \frac{99}{7} = 14.14 \text{ minutes}$$

$$\text{Element 4} = \frac{3+4+5+4+3}{5} = \frac{19}{5} = 3.8 \text{ minutes}$$

$$\text{Element 5} = \frac{5+6+8+7+6+7}{6} = \frac{39}{6} = 6.5 \text{ minutes}$$

Calculating normal time for each task element:

Normal time = Observed time × Performance rating

Element 1 = $4.50 \times 1.10 = 4.95$ minutes

Element 2 = $6.71 \times 0.90 = 6.04$ minutes

Element 3 = $14.14 \times 1.05 = 14.85$ minutes

Element 4 = $3.80 \times 1.00 = 3.8$ minutes

Element 5 = $6.50 \times 1.30 = 8.45$ minutes

Normal time for the process:

Normal time for process = Sum of normal times for elements

$= 4.95 + 6.04 + 14.85 + 3.8 + 8.45$

$= 38.09$ minutes

Standard time for process:

$$\text{Standard time for process} = \frac{\text{Normal time for process}}{1 - \text{Allowance factor}} = \frac{38.09}{1 - 0.20} = 47.6 \text{ minutes (rounded)}$$

(b) *Calculating sample size:*

Job Element	Mean Observed Time ($\bar{X}$)	Desired Accuracy (h)	Std. Dev. Required (Z)	Std. Dev. of Sample (S)	Samples Required
Select correct muffler	4.50	0.05	1.96	0.836	53
Remove old muffler	6.71	0.05	1.96	0.755	20
Weld/install new muffler	14.14	0.05	1.96	1.345	14
Check/inspect work	3.80	0.05	1.96	0.836	75
Complete paperwork	6.50	0.05	1.96	1.048	40

$$n = \left(\frac{zs}{h\bar{x}}\right)^2 = \left[\frac{(1.96)(0.836)}{(0.05)(3.8)}\right]^2 = 75$$

Element 4 required a sample of 75, thus the sample size for the study is 75.

S10.23 Sample size $= \dfrac{Z^2 p(1-p)}{h^2} = \dfrac{2.0^2 \times .15 \times .85}{.04^2} = 319.$

Therefore, minimum sample size is 319 samples.

S10.24 $n = \left(\dfrac{Z}{h}\right)^2 p(1-p) = \left(\dfrac{2.33}{0.05}\right)^2 (0.2)(0.8) = 347$ (rounded up)

S10.25

(a) Standard time in minutes per chair = 480 minutes per day/130 chairs
= 3.69 minutes

(b) Total allowances = 18% (6 + 6 + 6 = 18)
Normal time = Standard time × (1 – Allowance time)
Therefore:
3.69 × (1 – .18) = 3.69 × .82 = 3.026 minutes = Normal time

S10.26 858 + 220 + 85 = 1,163

$$\% \text{ spent working} = \frac{858}{1{,}163} = 0.738 = 73.8\%$$

S10.27 (a) $\dfrac{250}{300} = .833 = 83.3\%$

(b) $n = \dfrac{Z^2 p(1-p)}{h^2}$

= (at 95% confidence level and 3% acceptable error)

$$n = \frac{(1.96)^2(0.167)(0.833)}{(0.03)^2}$$

$$= \frac{(3.84)(0.167)(0.833)}{0.0009} \cong 594$$

(c) The sample size was only about half the desired size.

S10.28

	Motion	TMU's
1	Reach 4 inches for the pencil	6
2	Grasp pencil	2
3	Move pencil 6 inches	10
4	Position the pencil	20
5	Insert the pencil into the sharpener	4
6	Sharpen the pencil	120
7	Disengage the pencil	10
8	Move the pencil 6 inches	10
		182

Given that 1 TMU = 0.0006 minutes: Time = 182 × 0.0006 = 0.1092 minutes (6.55 seconds)

S10.29 Tell the supervisor that delay was over 8% and the sample size was adequate (for a 95% confidence and 3% acceptable error):

Delay:

$$\frac{105}{1200} = 0.0875 = 8.75\%$$

Sample size:

$$n = \frac{(1.96)^2(0.0875)(1-0.0875)}{(0.03)^2}$$

$$= \frac{(3.84)(0.0875)(0.9125)}{0.0009} = 341$$

S10.30

(a) Minutes available per day = 6 hours – 2 hours
= 4 × 60 min = 240 min

(b) Minutes of room cleaning required
200 room @ 30 min each = 6,000 minutes
200 room @ 15 min each = 3,000 minutes
Total of 9,000 minutes = 150 hours

(c) Each employee can clean 8 rooms (4 hr/.5 hr = 8)
Each employee can refresh 16 rooms
(4 hr/.25 hr = 16)
Total housekeepers needed today $= \dfrac{9{,}000 \text{ min.}}{240 \text{ min.}} = 37.5 \approx 38$

(d) 400 room @ .5 hr each = 200 hr
200/4 = 50 employees required to thoroughly clean all 400 rooms.

CASE STUDY

JACKSON MANUFACTURING CO.

1. Cycle times

x	$\bar{x}$	$x - \bar{x}$	$(x - \bar{x})^2$
2.05	1.90	0.1488	0.0221
1.92	1.90	0.0188	0.0004
2.01	1.90	0.1088	0.0118
1.89	1.90	–0.0112	0.0001
1.77	1.90	–0.1312	0.0172
1.80	1.90	–0.1012	0.0102
1.86	1.90	–0.0412	0.0017
1.83	1.90	–0.0712	0.0051
1.93	1.90	0.0288	0.0008
1.96	1.90	0.0588	0.0035
1.95	1.90	0.0488	0.0024
2.05	1.90	0.1488	0.0221
1.79	1.90	–0.1112	0.0124
1.82	1.90	–0.0812	0.0066
1.85	1.90	–0.0512	0.0026
1.85	1.90	–0.0512	0.0026
1.99	1.90	0.0888	0.0079

$\bar{x} = 1.90$ $\qquad 0.1296 = \sum(x - \bar{x})^2$

$h = 0.05$, $n = 17$, $z = 3$

$$\text{Std. dev.} = 0.0899 = \sqrt{\frac{\sum(x-\bar{x})^2}{n-1}} = \sqrt{\frac{0.1296}{16}}$$

$$\text{Sample size required} = \left(\frac{zs}{h\bar{x}}\right)^2 = \left(\frac{3 \times 0.0899}{.05 \times 1.9}\right)^2 = 8.07 \approx 8$$

This can be rounded up to 9 for statistical accuracy.

2. A sample size of 17 is more than adequate, given the low variation in cycle times; indeed, a sample size of 8 or 9 would be adequate.

3. Available time = 7.5 × 60 = 450 minutes

Cycle time = 1.90; normal time = 1.90 × 1.15 = 2.185

$$\text{Std. time} = \frac{2.185}{1-.16} = \frac{2.185}{.84} = 2.60 \text{ minutes}$$

$$\text{Number of units processed} = \frac{450}{2.60} = 173.10 \approx 173$$

4. \$100 = (\$1250 × 8.0) = Total cost per day

So, $\qquad \frac{\$100}{173} = \$.578$ per unit

INTERNET CASE STUDY*

CHICAGO SOUTHERN HOSPITAL

1. Sampling plan:

- Do studies on all shifts (probably four shifts; three each day plus the weekend shift) to get data on workload differences by shift. Then cross-check with other studies by function (intensive care, maturity, postoperation, etc.). If identifiable differences are present, then judgments will need to be made about additional studies.
- It may well be that major differences exist, suggesting that more extensive studies be made.
- Generate a random sample of which nurse to sample when using a true random device, such as the random number table provided in the text in Appendix III.
- Perform an adequate number of samples (per question 2).

2. $$\text{Sample size} = n = \frac{Z^2 \times p(1-p)}{h^2} = \frac{(1.96)^2 \times (0.15)(0.85)}{(0.04)^2}$$

$$= \frac{3.84 \times 0.1275}{0.0016} = \frac{0.49}{0.0016} = 306.13 \Rightarrow 306$$

Note: The sample size will change if the 15% vs. 85% is not close to accurate. This difference may suggest that a larger sample be taken.

3. By structuring the study across different nurses, different shifts, and different hospital processes (areas/functions), there should be an adequately diverse cross section. Some postsample check to ensure a mix of nurses, shifts, and functions should be made.

* This case study is found at our Companion Web site, www.prenhall.com/heizer.