Chapter 13

Work Sampling

13 Introduction

Work sampling is a statistical technique used to estimate the proportion of time spent on different activities in a workplace. It involves taking random samples of observations over a period to determine how work is distributed among different tasks. It is primarily used for non-repetitive tasks, but may be used for repetitive tasks, and there is no upper boundary on how long the task may take.

Work sampling is the observation of an employee at random intervals over an extended period. The analyst goes to the employee's normal work area and records what the employee is doing when the analyst first sees the employee (not what the employee starts doing after the employee sees the analyst).

An example would be a janitor that cleans offices. The tasks performed may be empty trash cans, vacuum carpets, dust furniture, mop floor, clean glass on doors, plus a variety of other duties that may only be done once a week or once a month. This job could be direct time studied but due to the wide variety of tasks it would probably require a significant amount of time to capture everything this individual does. The alternative is to do work sampling on this job. (Note: Although all the above tasks are work tasks, you would **not** group them all together into one category called WORK.)

Several times each day the analyst will, at random times, find this employee and observe which activity the individual is engaged in at the exact moment the analyst first sees the employee. This activity is recorded as an observation on the data collection page. After enough observations have been collected (usually a hundred or more), the relative amount of time the individual spends in each activity can be estimated. For example, if the janitor was observed mopping the floor on 32 occasions out of 200 total observations, then the mopping activity would account for 16% of that person's duties (32/200).

13.1 Major Uses of Work Sampling

Work sampling is appropriate for the following workplace objectives.

1. *Measuring Work Performance:*
    - Estimate the proportion of time employees spend on productive vs. non-productive tasks.
    - Identify time-wasting activities and areas for improvement.
2. *Determining Utilization Rates:*
    - Assess the utilization of machinery and equipment.

- Identify underutilized resources and opportunities for better allocation.

3. *Setting Standards:*
    - Develop performance standards based on actual observed data.
    - Create benchmarks for different tasks and operations.
4. *Analyzing Work Distribution:*
    - Understand how work is distributed across different tasks and employees.
    - Identify bottlenecks and workload imbalances.
5. *Delay studies:*
    - Used to determine the percentage of a person's normal workday when they aren't doing their assigned job. This yields both the personal factor and delay factor used in P, F, and D percentage.

13.2 Work Sampling Procedure

The following steps describe a typical work sampling procedure.

1. *Define the Purpose and Scope:*
    - Identify the specific activities or operations to be studied.
    - Define the time period for the study and the level of detail required.
2. *Design the Study:*
    - Determine the sample size based on the desired confidence level and precision.
    - Develop a sampling plan that specifies when and where observations will be taken.
3. *Collect Data:*
    - Conduct <u>*random*</u> observations according to the sampling plan.
    - Record the activities being performed at each observation point.
4. *Analyze Data:*
    - Compile and categorize the collected data.
    - Calculate the proportion of time spent on each activity.
5. *Interpret Results:*
    - Use the data to identify patterns and inefficiencies.
    - Make recommendations for improvements based on the findings.

13.3 Examples of Work Sampling Applications

Work sampling has numerous applications in every industry. The following examples illustrate this point.

1. **Manufacturing:**
   - Evaluating machine utilization and operator efficiency.
   - Identifying downtime causes and optimizing maintenance schedules.
   - A study to determine the proportion of time machine operators spend on actual machining, setup, maintenance, and idle time.
   - A study to determine the proportion of time workers in each department spend in major categories.
2. **Service Industries:**
   - Assessing the efficiency of service delivery in healthcare, hospitality, and retail.
   - Measuring customer service activities and identifying areas for improvement.
3. **Administrative Work:**
   - Analyzing office activities to identify non-value-added tasks.
   - Analyze office staff to see how their time is allocated between different types of work, meetings, events, training, and other duties.
   - Streamlining administrative processes and improving productivity.
4. **Healthcare Facility:**
   - Analyzing how nurses allocate their time between direct patient care, administrative tasks, and other duties.
5. **Retail Store:**
   - Observing how sales associates split their time between assisting customers, restocking shelves, and performing cashier duties.

13.4 Advantages and Disadvantages of Work Sampling

Work sampling is a simple, yet powerful, technique that offers several advantages and disadvantages compared to other work measurement techniques.

13.4.1 Advantages of Work Sampling

The following describes some advantages afforded by work sampling.

1. *Cost-Effective:*
   - Requires fewer resources and less time compared to continuous observation techniques.
2. *Minimal Disruption:*
   - Causes less interference with normal operations since observations are random and spread out.

- Can be performed by a technician with minimal training.

3. *Broad Scope:*
    - Can cover a wide range of activities and provide a comprehensive overview of work distribution.
    - Suitable for non-repetitive jobs or for jobs with long cycle times.
    - Several people or machines can be observed simultaneously.
    - Can be done over a long time period (i.e., weeks, months) to detect all types of variables. The results will be more representative of the job than direct time studies over short time periods.
4. *Flexibility:*
    - Can be applied to various industries and types of work environments.

13.4.2 Disadvantages of Work Sampling

Despite its ease of use and other advantages, disadvantages associated with work sampling include

1. *Statistical Variability:*
    - The accuracy of results depends on the number of observations and adherence to random sampling principles.
2. *Potential Bias:*
    - Observers may unintentionally influence the behavior of workers if they are aware of being observed (Hawthorne effect).
3. *Data Interpretation:*
    - Requires careful analysis and understanding of statistical principles to draw valid conclusions.
4. *Limited Detail:*
    - Provides an overview rather than detailed insights into specific tasks or processes.
    - Method variations are usually not detected by work sampling.

Example 1. Work Sampling to Machine Downtime

A total of 100 observations were made at random times during a one-week period (a total of 40 hours) in a corrugated box converting department, which consists of 10 different machines. Each observation was identified and classified into one of the following downtime categories in the table below. How many hours per week did an average machine spend in each category?

Category	No. of observations
Maintenance breakdown	25
Ink washups	9
Internal adjustments by operator	12
Waiting on stock	20
Waiting for help to arrive	6
Break time	10
Blocking	10
Starving	8
Total	100

Solution:

The proportions of time spent in each category was determined as the number of observations in each category divided by 100 total observations. Time spent in each category was determined by multiplying the category proportion by total hours for the week (40 hr).

Category	Proportion	Hrs per category
Maintenance breakdown	25/100 = 0.25	0.25 x 40 = 10.0
Ink washups	9/100 = 0.09	0.09 x 40 = 3.6
Internal adjustments by operator	12/100 = 0.12	0.12 x 40 = 4.8
Waiting on stock	20/100 = 0.20	0.20 x 40 = 8.0
Waiting for help to arrive	6/100 = 0.06	0.06 x 40 = 2.4
Break time	10/100 = 0.10	0.10 x 40 = 4.0
Blocking	10/100 = 0.10	0.10 x 40 = 4.0
Starving	8/100 = 0.08	0.08 x 40 = 3.2
Total	= 1.0	= 40

Example 2. Work Sampling Study on Self

To gain some experience and familiarity with Work Sampling, you can do a Work Sampling Study on yourself for a two-day period. If you wish, the study may begin today and then continue for eight hours. If you start at the beginning of a day, then the study should start at least one hour after you awaken and continue for the next eight hours. The two days of study may be done on any day of the week. The two days need not to be consecutive. About every 15 minutes, record what you are doing at that moment in time. Keep a small notepad with you for the two-day study period and write the time of day and the activity in your notepad. You will have 32 observations per day for a total of 64 observations at the end of two days. At the end of the two days summarize all the activities into major categories and provide a summary of your results. (Note: Personal activities and delay activities are separate categories in all work sampling studies, and they are shown as the first items on the work sampling study summary page, or they may be shown as the last items on the summary page.)

For example, at the end of your two-day study you might have the following activities listed at different times over the two day period:

Wednesday - 7:45 A.M. - Drive to work.
Wednesday - 5:15 P.M. - Drive to grocery store.
Thursday - 5:30 P.M. - Drive to pick up kids.
Thursday - 6:15 P.M. - Drive home.

Although the destination in all four of the above activities was different, you should group this set of activities into one major category called Driving. It is not advisable to Drive and write in your notebook simultaneously, so some of your observations will need to be recorded a short time after the activity for practical reasons. However, you should not wait until the end of the day and then try to remember what you did during the day. Record your activities as close as possible to the actual time they happened (within reason).

Personal Activities, such as Brush Teeth, do not need to be detailed as Brush Teeth in the Final Summary, but are recorded simply as a Personal Activity. Group all personal activities together into one category when you prepare your final summary.

Delay Activities, such as being put on hold while using the telephone, should also be grouped together into one category when you prepare your final summary.

To successfully complete this Work Sampling self-study, complete the Work Sampling Record Form that follows. This is a three-page form, and it contains the following information:

1. A list of the activities performed during each of the two days in the original order in which they happened showing the time the activity occurred. You should have 64 individual observations in chronological order. A brief example is below.
2. A summary of the activities into between 7 to 20 major categories. A brief example is below.

Work Sampling Daily Record of Activities

First Date of Study:

Number	Time	Activity Description	Category
1	8:30 AM	Eat Breakfast	
2	8:45 AM	Brush Teeth	
3	9:00 AM	Read HW Instructions	
4	9:15 AM	Read HW Instructions	
5	9:30 AM	Read TV Guide Magazine	
6	9:45 AM	Watch TV	

Continue recording activities in the above list until you have a total of 64 observations over the two-day period.

At the end of the two days, review your activities and then add the Major Category title beside each activity. For example, the first activity above "Eat Breakfast" would be labeled as "Personal" in the above Category Column.

Then, summarize all the activities into a table as shown in the following example:

Work Sampling Record
Summary of Activities into Major Categories

Major Category	Number of Observations	Percent of Total Time
Driving	5	7.8%
Walking	8	12.5%
Studying	5	7.8%
Shopping	10	15.6%
Mow Yard	2	3.1%
Wash Dishes	3	4.7%
Change Flat Tire on Car	2	3.1%
Do Laundry	3	4.7%
Personal (Watch TV, etc.)	20	31.3%
Delay (Wait in Line, etc.)	6	9.4%
Totals	64	100.0%

A Work Sampling template is provided in Figure 13.1.

Work Sampling Daily Record of Activities

First Date of Study:

Number	Time	Activity Description	Category
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
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21			
22			
23			
24			
25			
26			
27			
28			
29			
30			
31			
32			

Work Sampling Daily Record of Activities

Second Date of Study:

Number	Time	Activity Description	Category
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
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29			
30			
31			
32			

Work Sampling Record
Summary of Activities into Major Categories

Major Category	Number of Observations	Percent of Total Time
Totals		

13.5 Determining Minimum Sample Size

One of the primary variables in any measurement procedure is the size of the sample, referred to as "n." To compute the value of n, we need three numerical values:

1. A Z-value based on an alpha value (alpha is the chance of being wrong),
2. An estimate of the variability of the process, and
3. How much error we are prepared to accept in our answer.

We will examine each of the above three values one-at-a-time.

13.5.1 The Z-Value

Alpha, $\propto$, is the chance, or probability, of reaching the wrong conclusion despite the evidence at hand. For example, if we desire to be 95% confident in our conclusion, then $\propto$ would be equal to 5%, or 0.05.

Once we know the $\propto$ value, we can use the simplified Z Table shown in Table 13.1 below to find our Z-value. Note that for large sample sizes or if the distribution of the data is known to be normal, we use the z-values. However, for small sample sizes and an unknown probability distribution of the data (i.e., $n < 30$), we typically use the Student's t test values. Observe that the Z-values in Table 13.1 are for a two-sided hypothesis test. To use the table below, we simply need to know the total alpha value and we look that number up in the alpha column. We then get the correct Z value from the column beside the alpha value. Continuing with our example above, if alpha is 0.050 then Z is 1.960 from the table below.

Table 13.1. Simplified Z Table Based on Alpha Values

Alpha	Z Value
0.003	2.970
0.005	2.810
0.010	2.575
0.020	2.327
0.030	2.170
0.040	2.054
0.050	1.960
0.060	1.881
0.070	1.813
0.080	1.751
0.090	1.696
0.100	1.645
0.150	1.439
0.200	1.282

13.5.2 Variability

We also need an estimate of the variability of the process.

If we are working with **variable data** (which is numerical measurement data, such as length, weight, diameter, time), this would be the standard deviation of the process (s).

If we are working with **attribute data** (which is pass or fail data, such as the percent wrong), this would be the sample proportion (p).

13.5.3 Acceptable Error

The error factor represents how much error we are prepared to tolerate in our answer. If we want 100% certainty in our conclusion, then we will have to look at the entire population of interest, or n = N. If we can tolerate something less than 100% certainty, then our value of "n" can be smaller. The more error we are willing to accept, the smaller the "n" value will be. Hence, an inverse relationship exists between the sample size, n, and the error tolerance level. There are many costs associated with "n" and the value of "n" should be as small as practical to minimize those expenses.

We will call the acceptable error term "e" and it will be equal to a range of how far away from the mean (or average or proportion) we can be, and still feel comfortable with our answer. This is also called the “half-width” or “margin of error.”

In many cases, the acceptable error may be specified or given. If the error is not given, then we can estimate a reasonable value as follows:

If we are working with variable data, the error can be set equal to approximately one-half of the standard deviation, or

$$e = \frac{s}{2} \tag{14.1}$$

If we are working with attribute data, the error can be set equal to approximately one-half of the proportion, or

$$e = \frac{p}{2} \tag{14.2}$$

13.5.4 The Two Equations

The equations for computing the sample size (n) are as follows:

Variable data:

$$n = \left[\frac{(z_{\propto/2})(s)}{e}\right]^2 \tag{14.3}$$

Or

$$n = \left[\frac{\left(t_{\propto/2,n-1}\right)(s)}{(k)(\bar{x})}\right] \tag{14.4}$$

Attribute data:

$$n = \left[\frac{\left(z^2_{\propto/2}\right)(\hat{p})(1-\hat{p})}{e^2}\right] \tag{14.5}$$

Example 3. Minimum Sample Size for Variable Data

A manufacturing operation has an average time-studied time of 0.750 minutes. The standard deviation of this operation is 0.055 minutes, based on the time study data. If we are interested in obtaining a time-studied estimate that is within 0.020 minutes of the true average for this job, with an ∝ value of 6%, how large a sample must be taken?

∝ = 6% or 0.060
Therefore, from the Z Table, $z_{\propto/2} = 1.881$
s = sample standard deviation = 0.055 min
e = error tolerance level = 0.020 min

Solution:

Time is variable data, so the minimal sample size is:

$$n = \left[\frac{(z_{\propto/2})(s)}{e}\right]^2 = \left[\frac{(1.881)(0.055)}{0.02}\right]^2 = 26.757, or\ 27\ observations$$

∴ We need 27 observations to be 94% confident that the sample manufacturing operation time of 0.750 minutes is within $\pm$ 0.020 minutes of the true average for this job.

When determining the final value of "n" we always round up to the next whole number, as in the above example.

Example 4. Minimum Sample Size for Variable Data

Seven cycles have been observed during a direct time study. The mean for the largest element time = 0.85 min, and the corresponding sample standard deviation s = 0.15 min, which was also the largest. If the analyst wants to be 95% confident that the mean of the sample was within +/- 10% of the true mean, how many more observations should be taken?

Let k = E = error tolerance level

Solution:

For *dof* = 6 degrees of freedom and α = 0.05, $t_{\alpha/2,n-1}$ = $t_{0.025,6}$ = 2.447

$$n = \left[\frac{(t_{\propto/2,n-1})(s)}{(k)(\bar{x})}\right]^2 = \left[\frac{(2.447)(0.15)}{(0.10)(0.85)}\right]^2 = \left[\frac{0.36705}{0.085}\right]^2 = (4.318)^2 = 18.647 \sim 19\ total\ obs.$$

$\therefore$ We need $19 - 7 = 12$ more observations

Example 5. Minimum Sample Size for Attribute Data

If we have a job that has a P, F, and D percentage of 25%, and we want our answer to be within 2% of the true percentage, with an $\propto$ value of 10%, how large a sample must be taken?

$\propto$ = 10% or 0.10
Therefore, from the Z Table, $z_{\propto/2} = 1.645$
$\hat{p}$ = sample proportion = 25% or 0.25
e = error tolerance level = 2% or 0.02

Solution:

Percentages are attribute data, so the minimum sample size is:

$$n = \left[\frac{\left(z_{\propto/2}^2\right)(\hat{p})(1-\hat{p})}{e^2}\right] = \left[\frac{(1.645^2)(0.25)(0.75)}{0.02^2}\right] = 1{,}268.449, or\ 1{,}269\ observations$$

∴ We need 1,269 observations to be 90% confident that the sample P, F, and D percentage of 25% is within $\pm$ 2% of the true percentage for this job.

The reason we have such a large sample size in the above example is due to our very small specified acceptable error level of 2%. If we were to increase our acceptable error value to 8%, the minimum sample size would be as follows:

$\propto$ = 10% or 0.100
Therefore, from the Z Table, $z_{\propto/2} = 1.645$
$\hat{p}$ = sample proportion = 25% or 0.25
e = error tolerance level = 8% or 0.08

Therefore, the minimum sample size is:

$$n = \left[\frac{\left(z_{\propto/2}^2\right)(\hat{p})(1-\hat{p})}{e^2}\right] = \left[\frac{(1.645^2)(0.25)(0.75)}{0.08^2}\right] = 79.277, or\ 80\ observations$$

∴ We need 80 observations to be 90% confident that the sample P, F, and D percentage of 25% is within $\pm$ 8% of the true percentage for this job.

Example 6. Minimum Sample Size for Attribute Data

The allowance factor for personal time, fatigue, and delay (PF&D) is to be determined in the finishing area. If it is estimated that the proportion of time per day is spent in these three categories (personal time, fatigue, and delay are grouped together to obtain one proportion) is 0.15, determine how many observations would be required to be 95% confident that the estimated proportion is within ±0.03 of the true proportion?

Solution:

$\propto$ = 5% or 0.05
Therefore, from the Z Table, $z_{\propto/2} = 1.96$
$\hat{p}$ = sample proportion = 15% or 0.15
e = error tolerance level = 3% or 0.03
Therefore, the minimum sample size is:

$$n = \left[\frac{\left(z_{\propto/2}^{2}\right)(\hat{p})(1-\hat{p})}{e^{2}}\right] = \left[\frac{(1.96^{2})(0.15)(0.85)}{0.03^{2}}\right] = 544.227, or\ 545\ observations$$

∴ We need 545 observations to be 95% confident that the sample P, F, and D percentage of 15% is within $\pm$ 3% of the true percentage for this job.

13.6 The (100 - ∝)% Confidence Interval (CI)

13.6.1. Confidence Interval for Variables Data

Variables data refers to continuous data that can be measured on a scale (e.g., length, weight, time). The $(1{-}\propto)\%$ CI for variables data is given as

$$(1{-}\propto)\%\ CI = \bar{x} \pm z_{\propto/2}\left(\frac{s}{\sqrt{n}}\right) \tag{14.6}$$

where:

- $\bar{x}$ = sample mean
- $z_{\propto/2}$ = z-value from the standard normal distribution for the desired confidence level (i.e., 1.96 for 95% confidence)
- s = sample standard deviation
- *n* = sample size

Example 7. Confidence Interval for Variables Data

Suppose we have a sample of 30 parts with a mean length of 50 mm and a standard deviation of 2 mm. What is the 95% confidence interval for the mean length?

Solution:

$$95\%\ CI = \bar{x} \pm z_{\propto/2}\left(\frac{s}{\sqrt{n}}\right) = 50 \pm 1.96\left(\frac{2}{\sqrt{30}}\right) = (49.284, 50.716)$$

∴ The 95% confidence interval for the mean length is between 49.284 mm and 50.716 mm.

13.6.2. Confidence Interval for Attributes Data

Attributes data refers to categorical data (e.g., pass/fail, defect/no defect). The $(1-\propto)\%$ CI for variables data is given as

$$(1-\propto)\%\ CI = \hat{p} \pm z_{\propto/2}\sqrt{\frac{\hat{p}(1-\hat{p})}{n}} \tag{14.7}$$

where:

- $\hat{p}$ = sample proportion
- $z_{\propto/2}$ = z-value from the standard normal distribution for the desired confidence level (i.e., 1.96 for 95% confidence)
- *n* = sample size

Example 8. Confidence Interval for Attributes Data

Suppose we have a sample of 200 products, and 30 are found to be defective. What is the 95% confidence interval for the proportion of defective products?

Solution:

$$\hat{p} = \frac{30}{200} = 0.15$$

$$95\%\ CI = \hat{p} \pm z_{\propto/2}\sqrt{\frac{\hat{p}(1-\hat{p})}{n}} = 0.15 \pm 1.96\sqrt{\frac{(0.15)(0.85)}{200}} = (0.1005, 0.1995)$$

∴ The 95% confidence interval for the proportion of defective products is between 10.05% and 19.95%.

13.7 Summary

Work sampling is a versatile and valuable tool in industrial engineering for assessing and improving work efficiency. It is appropriate to use for broad, less detailed analysis of work distribution and efficiency, and is particularly useful in environments where continuous observation is impractical. Its primary advantages include its ease of use, broad scope, and minimal disruptions. Conversely, its primary disadvantages are that it is a less accurate work measurement technique compared to direct time study and PMTS, it may not detect method variations, and statistical accuracy is subject to an appropriate sample size of random observations. By understanding its methodology, applications, and limitations, engineers can effectively utilize work sampling to evaluate the proportion of time people spend in different activities, proportion of time a machine spends in different delay activities, etc.

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References

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[2] Groover, M.P. *Work Systems and the Methods, Measurement, and Management of Work*, Upper Saddle River, NJ: Pearson Prentice Hall, 2007.

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Chapter 13

Review Questions

13.1 Define work sampling.

13.2 What are the characteristics of work situations for which work sampling is most suited?

13.3 What are some of the common applications of work sampling?

13.4 What is a biased estimate in work sampling?

13.5 On what kinds of jobs or tasks is work sampling an appropriate technique for setting time standards?

13.6 What is meant by the term sampling stratification?

13.7 What are some of the advantages of work sampling? Name three.

13.8 What are some of the disadvantages and limitations of work sampling? Name three.

Problems

13.1 The allowance factor for personal time, fatigue, and delay (PF&D) is to be determined in the machine shop area. If it is estimated that the proportion of time per day is spent in these three categories (personal time, fatigue, and delay are grouped together to obtain one proportion) is 0.12, determine how many observations would be required to be 95% confident that the estimated proportion is within ±0.02 of the true proportion?

13.2 The foreman in the welding department wanted to know what value of allowance to use for a particular section of the shop. A work sampling study was authorized. Only two activity categories were considered: (1) welding and other productive work, and (2) personal time, rest breaks, and delays. Over a four-week period (40 hours/week), 125 observations were made at random times. Each observation captured the category of activity of each of eight welders in the shop section of interest. Results indicated that category 2 constituted 33% of the total observations. (a) Define the limits of a 96% confidence interval for activity 2. (b) If a total of 725 work units were produced during the 4 weeks, and all category 1 activity was devoted to producing these units, what was the average time spent on each unit?

13.3 A work sampling study was performed during a three-hour final exam to determine the proportion of time that students spend using a calculator. There were 70 students taking the exam. A total of five observations were taken of each student at random times during the three hours. Of the total observations taken, 77 of the observations found the students using their calculators. (a) Form a 90% confidence interval on the proportion of time students spend using their calculators during an exam. (b) How many observations must be taken for the analyst to be 95% confident that the estimate of proportion of time a student uses a calculator is within ±3% of the true proportion?

13.4 The Chief IE in the production department wanted to know what value of PFD allowance to use for a particular section of the shop. A work sampling study was authorized. Only three activity categories were considered: (1) production work, (2) personal time, rest breaks, and delays, and (3) other activities. Over a four-week period (40 hours/week), 100 observations were made at random times. Each observation captured the category of activity of each of 22 production workers in the department. Results indicated that category 2 constituted 19% of the total observations. (a) Define the limits of a 95% confidence interval for activity 2. (b) If a total of 522 work units were produced during the 4 weeks, and the 1540 observations in category 1 activity were all devoted to producing these units, what was the average time spent on each unit?

13.5 A work sampling study is to be performed on an insurance office staff consisting of 15 persons to see how much time they spend processing claims. The duration of the study is 20 days, eight hours per day. Processing claims is only one of the activities done by the staff members. The office manager estimates that the proportion of time processing claims = 0.20. (a) At the 95 percent confidence level, how many observations are required if the upper and lower confidence limits are 0.16 and 0.24? (b) Regardless of your answer to (a), a total of 1200 observations were taken, and staff members were processing claims in 300 of those observations. Construct a 98 percent confidence interval for the true proportion of time processing claims. (c) Records for the period of the study indicate that 335 claims were processed. Estimate the average time per claim processed? (d) Determine a standard for processing claims but express the standard in terms of the number of claims processed per day (8 hours) per person. Assume a 100% performance rating and that no allowance factor is to be included in the standard.

13.6 A work sampling study is to be performed on an office pool consisting of 10 persons to see how much time they spend on the telephone. The duration of the study is to be 22 days, seven hours per day. All calls are local. Using the phone is only one of the activities that members of the pool accomplish. The supervisor estimates that 25% of the time of the workers is spent on the phone. (a) At the 95% confidence level, how many observations are required if the lower and upper limits on the confidence interval are 0.20 and 0.30. (b) Regardless of your answer to (a), suppose that 200 observations were taken on each of the ten workers (2000 observations total), and members of the office pool were using the telephone in 590 of these observations. Construct a 95% confidence interval for the true proportion of time on the telephone. (c) Phone records indicate that 3894 phone calls (incoming and outgoing) were made during the observation period. Estimate the average time per phone call.

13.7 The shop foreman has estimated that the proportion of time the machines in her department are idle is a mere 10%. On the basis of this estimate, a work sampling study is to be performed. (a) If we want a 95% confidence level that the true value of the proportion idle time is within ±2.5% of this 10% (that is, the confidence interval runs from 7.5% to 12.5%), how many observations must be taken? (b) Suppose after the study is taken with the number of observations from part (a), the proportion of observations is 15% rather than 10%. What is the range of the 95% confidence interval in this case? (c) How many more observations need to be taken to achieve a confidence interval of 15% ±2.5%?

13.8 A work sampling study has been performed on a women's college sorority to determine how much time the women spend at their desks reading homework assignments. The sorority consists of 30 women. The duration of the study was 4 weeks, 7 days per week, between the hours of 7:00 a.m. and 11:00 p.m. each day. It is assumed that no reading was done before 7:00 a.m. or after 11:00 p.m., since the sorority members observe a very strict work ethic code. Five observations were taken at random times each day, and each observation included all 30 women. Out of all the observations, a total of 1344 observations found the women reading homework assignments at their desks. (a) Construct a 95% confidence interval for the true proportion of time spent reading homework assignments. (b) What is the average time per day that each woman spends reading homework assignments? (c) If the women in the sorority collectively completed a total of 513 reading assignments during the observation period, how many hours did each assignment take, on average?

13.9 A work sampling study is to be performed on the art department in a publishing company. The department consists of 22 artists who work at computer graphics workstations developing line drawings based on authors' rough sketches. The duration of the study is 15 days, seven hours per day. Line drawings are the main activity performed by the artists, but not the only activity. The supervisor of the department estimates that the proportion of time spent making line drawings is 75% of each artist's day. (a) At the 95% confidence level, how many observations are required if the lower and upper confidence limits are 0.72 and 0.78, respectively. (b) Regardless of your answer in preceding part (a), a total of 1000 observations were taken, and artists were making line drawings in 680 of those observations. Construct a 97.5% confidence interval for the true proportion of time making line drawings. (c) Records for the period of the study indicate that 5,240 line drawings were completed. Estimate the average time per line drawing? (d) Determine the standard time for one line drawing, given that the average performance rating for the artists was observed to be 90%, and the allowance for personal time, fatigue, and delays is 15%.

13.10 A work sampling study was performed on the day-shift maintenance department in a power generating station. The dayshift consists of four repair persons, each of whom works independently to repair equipment when it breaks down. A total of 800 observations (200 observations per repair person) were taken during a four-week period (160 total hours of station operation). The observations were classified into one of the following categories: (1) maintenance person repairing equipment, or (2) maintenance person idle. There were a total of 432 observations in category 1. It is known that 83 equipment repairs were made during the 4 weeks. (a) How many more observations would be required, if any, to be 90% confident that the true proportion of category 1 activity is within $\pm$ 0.03 of the proportion indicated by the observations? Also, determine: (b) average time it takes a repair person to repair a piece of broken-down equipment, and (c) how many hours of idle time per week is experienced by each repair person, on average.

13.11 A work sampling study was performed on 12 assembly workers in a small electronics final assembly plant. Various products are made in small lot sizes, and it would not be cost effective to direct time study every job. However, the jobs can be distinguished on the basis of the size of the starting printed circuit board (PCB), and it is believed that work sampling might provide estimates of the average time per board size. There are three different PCB sizes: A (large), B (medium), and C (small). The study was carried out over a five-week period (25 8-hour days or 200 working hours). Observations were taken at random times four times each day for 25 days, for a planned total of 1200 observations (4 x 25 x 12). However, due to worker absences, 60 observations were omitted (15 worker-day absences). Results of the study are presented in the table below. (a) What is the mean assembly time per product unit for each of the three PCB sizes? (b) For the C size PCB assembly, construct a 96% confidence interval about the mean assembly time per product.

Category of activity	**A assembly**	**B assembly**	**C assembly**	**Miscellaneous**
Number of observations	228	285	456	171
Number of units completed	610	1127	3025	(none)

13.12 A work sampling study was performed on four account executives in a stockbroker's office. Virtually all sales in the office are made through telephone solicitations. A total of 500 observations were made over a period of one week (seven hours per day, five days per week). The categories of activity and number of observations per category were as follows: (1) telephone calls, 164; (2) filing and sorting, 150; (3) reading and research, 101; (4) personal and nonproductive time, 85. Total sales during this period were $525,000, on which the office earned a commission of 4.0%. (a) Construct a 97% confidence interval on the proportion of time on the telephone during the one-week period? (b) Estimate how many hours were spent on the phone by the four account executives during this period? (c) The office is considering hiring a clerk at $800/week to do the filing and sorting (category 2). This would reduce the time taken by the account executives on these activities by seven hours per day. It is anticipated that all of these extra seven hours would be spent on phone calls to increase sales. If sales level (in dollars) has been found to be proportional to time on the telephone, will the increase in commissions pay for the clerk? Compute the estimated net increase or decrease in weekly revenues from hiring the clerk.

13.13 A work sampling study was performed on 15 social workers in a county government office. The social workers handle three types of cases: A, single parents; B, foster parents; and C, juvenile delinquents. The purpose of the work sampling study was to determine estimates of the average time per case for each case type. In addition to the three case types, two additional activity categories were included in the study: D, traveling between cases; and E, other (miscellaneous) activities. The study was carried out over a five-week period (25 8-hour days or 200 working hours). Observations were taken at random times four times each day for 25 days, for a planned total of 1500 observations (4 x 25 x 15). Each social worker was provided with a cell phone so they could be contacted if they were not in the office building. Because of worker absences, 72 observations were omitted (18 worker-days of absences). Results of the study are presented in the table below. (a) What is the mean time per case for each of the three case types? (b) What is the average travel time spent on a case? (c) For the C type cases, construct a 92.5% confidence interval about the mean case time.

Category of activity	A cases	B cases	C cases	D Transport	E Other
Number of observations	314	272	350	388	104
Number of cases completed	439	725	273	(none)	(none)

Number of Cycles

13.14 Seven cycles have been observed during a direct time study. The mean for the largest element time = 0.85 min, and the corresponding sample standard deviation s = 0.15 min, which was also the largest. If the analyst wants to be 95% confident that the mean of the sample was within ±10% of the true mean, how many more observations should be taken?

13.15 A total of 9 cycles have been observed during a time study. The mean for the largest element time = 0.80 min, and the corresponding sample standard deviation s = 0.15 min, which was also the largest. If the analyst wants to be 95% confident that the mean of the sample was within ±0.10 min of the true mean, how many more observations should be taken?

13.16 A total of 6 cycles have been observed in a direct time study. The mean for the largest element time = 0.82 min, and the corresponding sample standard deviation s = 0.11 min, which was also the largest. If the analyst wants to be 95% confident that the mean of the sample was within ±0.10 min of the true mean, how many more observations should be taken?

13.17 Ten cycles have been observed during a direct time study. The mean time for the longest element was 0.65 min, and the standard deviation calculated on the same data was 0.10 min. If the analyst wants to be 95% confident that the mean of the sample was within ±8% of the true mean, how many more observations should be taken?

13.18 Six cycles have been observed during direct time study. The mean time for the longest element was 0.82 min, and the standard deviation calculated on the same data was 0.13 min. If the analyst wants to be 90% confident that the mean of the sample was within ±0.06 min of the true mean, how many more observations should be taken?

13.19 Six cycles have been observed during a direct time study. The mean for the largest element time = 1.00 min, and the corresponding sample standard deviation s = 0.10 min. (a) Based on these data, what is the 90% confidence interval on the 1.0 min element time? (b) If the analyst wants to be 90% confident that the mean of the sample was within ±10% of the true mean, how many more observations should be taken?

13.20 A total of 9 cycles have been observed during a direct time study. The mean for the largest element time = 1.30 min, and the corresponding sample standard deviation s = 0.20 min. (a) Based on these data, what is the 95% confidence interval on the 1.30 min element time? (b) If the analyst wants to be 98% confident that the mean of the sample was within $\pm$5% of the true mean, how many more observations should be taken?