WORK SAMPLING

IENG 301

FUNDAMENTALS OF WORK STUDY AND ERGONOMICS

Work Sampling

- Work Sampling is a fact finding tool. In many cases, needed information about men or machines can be obtained in less time and at lower cost by this method than by other means.

Work Sampling has three main uses:

1. Activity and Delay Sampling
   - To measure the activities and delays of workers or machines (e.g. to measure the percentage of the day that a person is working or not working).

2. Performance Sampling
   - To measure working time and nonworking time of a person on a manual task, and to establish a ***performance index*** or performance level for the person during his or her working time.

3. Work Measurement
   - To establish a time standard for an operation.

Work Sampling

- Work Sampling is based upon the laws of probability. A sample taken at random from a large group tends to have the same pattern of distribution as the large group or universe. If the sample is large enough, the characteristics of the sample will differ but little from the characteristics of the group.
  - Sample: is the term used for this small number
  - Population or Universe: is the term used for large group
  - Sampling: Obtaining and analyzing only a part of the universe

Example 1

- Working: 36 observations
- Idle: 4 observations
- Total: 40 observations

Percentage of;

- Idle time = (4/40 x 100) = 10%
- Working time = (36/40 x 100) = 90%

On an 8hr working day;

- 480 x 0.10 = 48 mins → the operator was idle
- 480 x 0.90 = 432 mins → the operator was working

The Normal Distribution Curve

- It is typical of the kind of frequency distribution which is of importance in Work Sampling because it represents graphically the probability of the occurrence of certain chance phenomena.

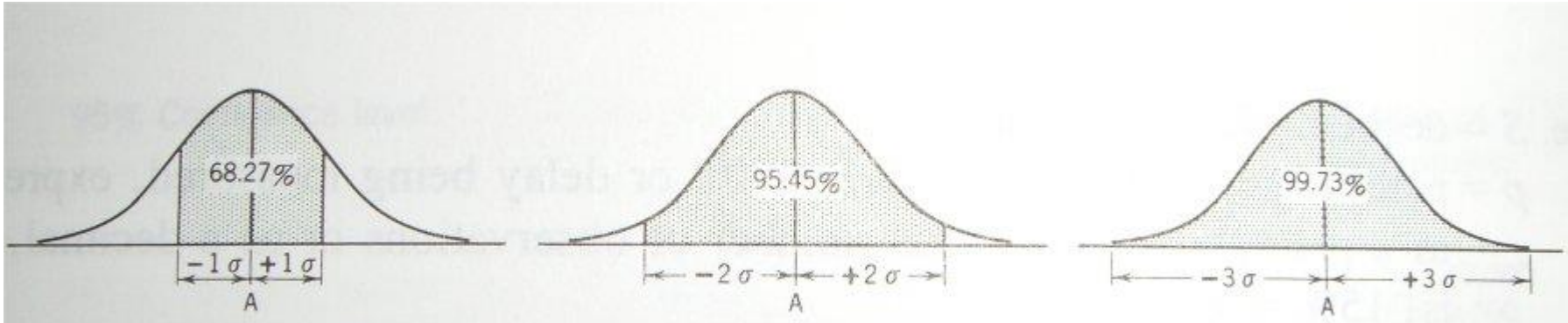

Figure 244 Areas under the normal curves.

The Normal Distribution Curve

- The formula for determining the sample size for a confidence level of 68% or 1 sigma is:

$$Sp = \sqrt{\frac{p(1-p)}{N}}$$

Where;

S: Desired relative accuracy
p: Percentage expressed as a decimal
N: Number of random observations (Sample Size)

The Normal Distribution Curve

- Fortunately, in Work Sampling study the analyst can determine in advance the number of observations needed for a given degree of accuracy.

- For many kinds of measurement an accuracy of ±5% is considered satisfactory. This is sometimes referred to as the standard error of the percentage.

Confidence Level

- The formula for determining the ***number of observations required*** is:

$$Sp = 2\sqrt{\frac{p(1-p)}{N}}$$

implies 2 confidence interval (CI) or 95% CI

Example 2

- Suppose that a total of 100 observations were made, and in this preliminary study 25 observations showed the machines to be idle. (S = ±5% = ±0.05)
- Therefore; the percentage of idle time = 25% (i.e. 25/100)

$$0.05p = 2\sqrt{\frac{p(1-p)}{N}}$$

$$0.0025p^2 = 4\left[\frac{p(1-p)}{N}\right] = \frac{4p(1-p)}{N}$$

$$N = \frac{4p(1-p)}{0.0025p^2} = \frac{4(1-p)}{0.0025p} = \frac{1600(1-p)}{p}$$

$$N = \frac{1600(1-0.25)}{0.25} = 4800 \text{ observations}$$

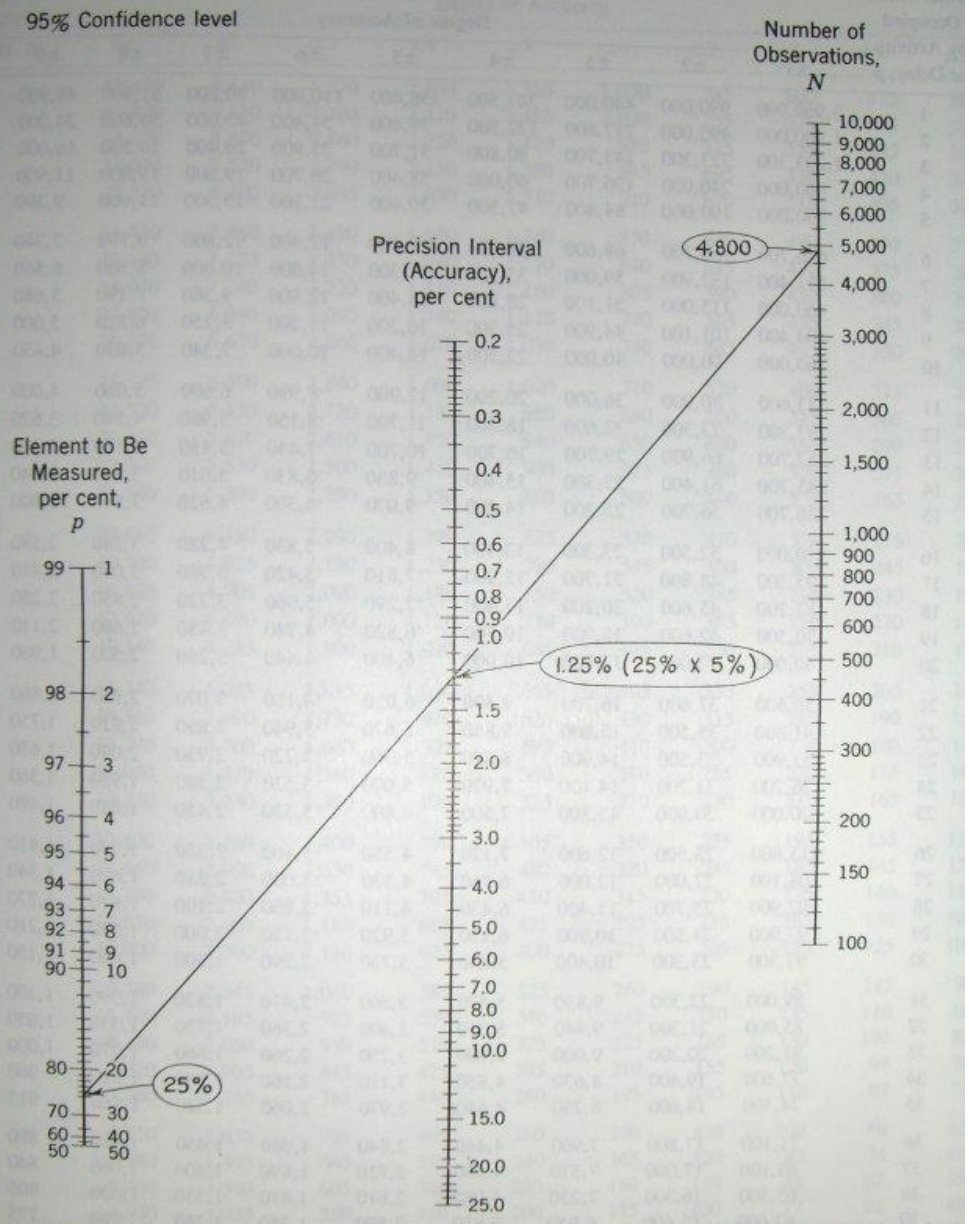

Figure 245 Alignment chart for determining the number of observations needed for a given degree of accuracy and value of p, 95% confidence level. (Courtesy Johns-Manville Corporation.)

Accuracy of Work Sampling Measurment

- **Note:** We can, by using the same formula to calculate the Accuracy (S) given the Number of observations (N).

- Absolute Error; (i.e. Sp) can be used to determine N. (see table 59 on page 422 and table 60, figure 246 and figure 247)

- Use of Random Number Tables to schedule the observations of work sampling. (see table 61 on page 424 and table 62 on page 428)

Table 56. Table for Determining the Number of Observations for a Given Degree of Accuracy and Value of p, 95% Confidence Level

Percent of Total Time Occupied by Activity or Delay, p	Degree of Accuracy									
	±1	±2	±3	±4	±5	±6	±7	±8	±9	±10
1	3,960,000	990,000	440,000	247,500	158,400	110,000	80,800	61,900	48,900	39,600
2	1,960,000	490,000	217,800	122,500	78,400	54,400	40,000	30,600	24,200	19,600
3	1,293,300	323,300	143,700	80,800	51,700	35,900	26,400	20,200	16,000	12,900
4	960,000	240,000	106,700	60,000	38,400	26,700	19,600	15,000	11,900	9,600
5	760,000	190,000	84,400	47,500	30,400	21,100	15,500	11,900	9,390	7,600
6	626,700	156,700	69,600	39,200	25,100	17,400	12,800	9,790	7,740	6,270
7	531,400	132,900	59,000	33,200	21,300	14,800	10,800	8,300	6,560	5,310
8	460,000	115,000	51,100	28,800	18,400	12,800	9,380	7,190	5,680	4,600
9	404,400	101,100	44,900	25,300	16,200	11,200	8,250	6,320	5,000	4,040
10	360,000	90,000	40,000	22,500	14,400	10,000	7,340	5,630	4,450	3,600
11	323,600	80,900	36,000	20,200	12,900	8,990	6,600	5,060	4,000	3,240
12	293,300	73,300	32,600	18,300	11,700	8,150	5,980	4,580	3,620	2,930
13	267,700	66,900	29,700	16,700	10,700	7,440	5,460	4,180	3,310	2,680
14	245,700	61,400	27,300	15,400	9,830	6,830	5,010	3,840	3,040	2,460
15	226,700	56,700	25,200	14,200	9,070	6,300	4,620	3,540	2,800	2,270
16	210,000	52,500	23,300	13,100	8,400	5,830	4,280	3,280	2,590	2,100
17	195,300	48,800	21,700	12,200	7,810	5,420	3,980	3,050	2,410	1,950
18	182,200	45,600	20,200	11,400	7,290	5,060	3,720	2,850	2,250	1,820
19	170,500	42,600	18,900	10,700	6,820	4,740	3,480	2,660	2,110	1,710
20	160,000	40,000	17,800	10,000	6,400	4,440	3,260	2,500	1,980	1,600
21	150,500	37,600	16,700	9,400	6,020	4,180	3,070	2,350	1,860	1,510
22	141,800	35,500	15,800	8,860	5,670	3,940	2,890	2,220	1,750	1,420
23	133,900	33,500	14,900	8,370	5,360	3,720	2,730	2,090	1,650	1,340
24	126,700	31,700	14,100	7,920	5,070	3,520	2,580	1,980	1,560	1,270
25	120,000	30,000	13,300	7,500	4,800	3,330	2,450	1,880	1,480	1,200
26	113,800	28,500	12,600	7,120	4,550	3,160	2,320	1,780	1,410	1,140
27	108,100	27,000	12,000	6,760	4,330	3,000	2,210	1,690	1,340	1,080
28	102,900	25,700	11,400	6,430	4,110	2,860	2,100	1,610	1,270	1,030
29	97,900	24,500	10,900	6,120	3,920	2,720	2,000	1,530	1,210	980
30	93,300	23,300	10,400	5,830	3,730	2,590	1,900	1,460	1,150	935
31	89,000	22,300	9,890	5,570	3,560	2,470	1,820	1,390	1,100	890
32	85,000	21,300	9,440	5,310	3,400	2,360	1,730	1,330	1,050	850
33	81,200	20,300	9,000	5,080	3,250	2,260	1,660	1,270	1,000	810
34	77,600	19,400	8,630	4,850	3,110	2,160	1,580	1,210	960	775
35	74,300	18,600	8,250	4,640	2,970	2,060	1,520	1,160	915	745
36	71,100	17,800	7,900	4,440	2,840	1,980	1,450	1,110	880	710
37	68,100	17,000	7,570	4,260	2,720	1,890	1,400	1,060	840	680
38	65,300	16,300	7,250	4,080	2,610	1,810	1,330	1,020	805	655
39	62,600	15,600	6,950	3,910	2,500	1,740	1,280	980	775	625
40	60,000	15,000	6,670	3,750	2,400	1,670	1,220	940	740	600
41	57,600	14,400	6,400	3,600	2,300	1,600	1,170	900	710	575
42	55,200	13,800	6,140	3,450	2,210	1,530	1,130	865	680	550
43	53,000	13,300	5,890	3,310	2,120	1,470	1,080	830	655	530
44	50,900	12,700	5,660	3,180	2,040	1,410	1,040	795	630	510
45	48,900	12,200	5,430	3,060	1,960	1,360	1,000	765	605	490
46	47,000	11,700	5,220	2,940	1,880	1,300	960	735	580	470
47	45,100	11,300	5,010	2,820	1,800	1,250	920	705	555	450
48	43,300	10,800	4,810	2,710	1,730	1,200	885	675	535	435
49	41,600	10,400	4,630	2,600	1,670	1,160	850	650	515	415
50	40,000	10,000	4,440	2,500	1,600	1,110	815	625	495	400

Table 57. Table for Determining the Degree of Accuracy for a Given Number of Observations and Value of p, 95% Confidence Level

Percent of Total Time Occupied by Activity or Delay, p	Number of Observations														
	10,000	9,000	8,000	7,000	6,000	5,000	4,000	3,000	2,000	1,000	900	800	700	600	500
1	±19.9	±21.0	±22.3	±23.8	±25.7	±28.1	±31.5	±36.3	±44.5	±62.9	±66.3	±70.4	±75.2	±81.3	±89.0
2	14.0	14.8	15.7	16.7	18.1	19.8	22.1	25.6	31.3	44.3	46.7	49.5	52.9	57.2	62.6
3	11.4	12.0	12.7	13.6	14.7	16.1	18.0	20.7	25.4	35.9	37.9	40.2	43.0	46.5	50.8
4	9.8	10.3	11.0	11.7	12.7	13.9	15.5	17.9	21.9	31.0	32.7	34.6	37.0	40.0	43.8
5	8.7	9.2	9.8	10.4	11.3	12.3	13.8	15.9	19.5	27.6	29.1	30.8	33.0	35.6	39.0
6	7.9	8.3	8.9	9.5	10.2	11.2	12.5	14.5	17.7	25.0	26.4	28.0	29.9	32.3	35.4
7	7.3	7.7	8.2	8.7	9.4	10.3	11.5	13.3	16.3	23.1	24.3	25.8	27.6	29.8	32.6
8	6.8	7.2	7.6	8.1	8.8	9.6	10.7	12.4	15.2	21.5	22.6	24.0	25.6	27.7	30.3
9	6.4	6.7	7.1	7.6	8.2	9.0	10.1	11.6	14.2	20.1	21.2	22.5	24.0	26.0	28.4
10	6.0	6.3	6.7	7.2	7.6	8.5	9.5	11.0	13.4	19.0	20.0	21.2	22.7	24.5	26.8
11	5.7	6.0	6.4	6.8	7.3	8.1	9.0	10.4	12.7	18.0	19.0	20.1	21.5	23.2	25.4
12	5.4	5.7	6.1	6.5	7.0	7.7	8.6	9.9	12.1	17.1	18.1	19.2	20.5	22.1	24.2
13	5.2	5.5	5.8	6.2	6.7	7.3	8.2	9.5	11.6	16.4	17.3	18.3	19.6	21.1	23.1
14	5.0	5.2	5.5	5.9	6.4	7.0	7.8	9.1	11.1	15.7	16.5	17.5	18.7	20.2	22.2
15	4.8	5.0	5.3	5.7	6.2	6.7	7.5	8.7	10.6	15.1	15.9	16.8	18.0	19.4	21.3
16	4.6	4.8	5.1	5.5	5.9	6.5	7.3	8.4	10.3	14.5	15.3	16.2	17.3	18.7	20.5
17	4.4	4.7	4.9	5.3	5.7	6.3	7.0	8.1	9.9	14.0	14.7	15.6	16.7	18.0	19.8
18	4.3	4.5	4.8	5.1	5.5	6.0	6.8	7.8	9.5	13.5	14.2	15.1	16.1	17.4	19.1
19	4.1	4.4	4.6	4.9	5.3	5.8	6.5	7.5	9.2	13.1	13.8	14.6	15.6	16.9	18.5
20	4.0	4.2	4.5	4.8	5.2	5.7	6.3	7.3	8.9	12.7	13.3	14.1	15.1	16.3	17.9
21	3.9	4.1	4.3	4.6	5.0	5.5	6.1	7.1	8.7	12.3	12.9	13.7	14.6	15.8	17.4
22	3.8	4.0	4.2	4.5	4.9	5.3	6.0	6.9	8.4	11.9	12.6	13.3	14.2	15.4	16.8
23	3.7	3.9	4.1	4.4	4.7	5.2	5.8	6.7	8.2	11.6	12.2	12.9	13.8	14.9	16.4
24	3.6	3.8	4.0	4.3	4.6	5.0	5.6	6.5	8.0	11.3	11.9	12.6	13.5	14.5	15.9
25	3.5	3.7	3.9	4.1	4.5	4.9	5.5	6.3	7.8	11.0	11.6	12.3	13.1	14.1	15.5
26	3.4	3.6	3.8	4.0	4.4	4.8	5.3	6.2	7.5	10.7	11.2	11.9	12.8	13.8	15.1
27	3.3	3.5	3.7	3.9	4.2	4.7	5.2	6.0	7.4	10.4	11.0	11.6	12.4	13.4	14.7
28	3.2	3.4	3.6	3.8	4.1	4.5	5.1	5.9	7.2	10.1	10.7	11.3	12.1	13.1	14.4
29	3.1	3.3	3.5	3.7	4.0	4.4	5.0	5.7	7.0	9.9	10.4	11.1	11.8	12.8	14.0
30	3.05	3.2	3.4	3.65	3.9	4.3	4.8	5.6	6.8	9.7	10.2	10.8	11.6	12.5	13.7
31	3.00	3.1	3.3	3.60	3.85	4.2	4.7	5.5	6.7	9.4	9.9	10.6	11.3	12.2	13.4
32	2.90	3.05	3.25	3.50	3.75	4.1	4.6	5.3	6.5	9.2	9.7	10.3	11.0	11.9	13.0
33	2.85	3.00	3.20	3.40	3.70	4.0	4.5	5.2	6.4	9.0	9.5	10.1	10.8	11.6	12.7
34	2.80	2.90	3.10	3.30	3.60	3.9	4.4	5.1	6.2	8.8	9.3	9.9	10.5	11.4	12.5
35	2.70	2.85	3.05	3.25	3.50	3.85	4.3	5.0	6.1	8.6	9.1	9.6	10.3	11.1	12.2

Table 59. Table for Determining the Number of Observations for a Given Absolute Error or Absolute Degree of Accuracy and Value of p, 95% Confidence Level

Percent of Total Time Occupied by Activity or Delay, p	Absolute Error (%)						Percent of Total Time Occupied by Activity or Delay, p	Absolute Error (%)					
	±1.0	±1.5	±2.0	±2.5	±3.0	±3.5		±1.0	±1.5	±2.0	±2.5	±3.0	±3.5
1	396	176	99	63	44	32	51	9,996	4,442	2,499	1,599	1,110	816
2	784	348	196	125	87	64	52	9,984	4,437	2,496	1,597	1,109	815
3	1,164	517	291	186	129	95	53	9,964	4,428	2,491	1,594	1,107	813
4	1,536	683	384	246	171	125	54	9,936	4,416	2,484	1,590	1,104	811
5	1,900	844	475	304	211	155	55	9,900	4,400	2,475	1,584	1,099	808
6	2,256	1,003	564	361	251	184	56	9,856	4,380	2,464	1,577	1,095	804
7	2,604	1,157	651	417	289	213	57	9,804	4,357	2,451	1,569	1,089	800
8	2,944	1,308	736	471	327	240	58	9,744	4,330	2,436	1,559	1,083	795
9	3,276	1,456	819	524	364	267	59	9,676	4,300	2,419	1,548	1,075	790
10	3,600	1,600	900	576	400	294	60	9,600	4,266	2,400	1,536	1,067	784
11	3,916	1,740	979	627	435	320	61	9,516	4,229	2,379	1,523	1,057	777
12	4,224	1,877	1,056	676	469	344	62	9,424	4,188	2,356	1,508	1,047	769
13	4,524	2,011	1,131	724	503	369	63	9,324	4,144	2,331	1,492	1,036	761
14	4,816	2,140	1,204	771	535	393	64	9,216	4,096	2,304	1,475	1,024	753
15	5,100	2,267	1,275	816	567	416	65	9,100	4,044	2,275	1,456	1,011	743
16	5,376	2,389	1,344	860	597	439	66	8,976	3,989	2,244	1,436	997	733
17	5,644	2,508	1,411	903	627	461	67	8,844	3,931	2,211	1,415	983	722
18	5,904	2,624	1,476	945	656	482	68	8,704	3,868	2,176	1,393	967	710
19	6,156	2,736	1,539	985	684	502	69	8,556	3,803	2,139	1,369	951	698
20	6,400	2,844	1,600	1,024	711	522	70	8,400	3,733	2,100	1,344	933	686
21	6,636	2,949	1,659	1,062	737	542	71	8,236	3,660	2,059	1,318	915	672
22	6,864	3,050	1,716	1,098	763	560	72	8,064	3,584	2,016	1,290	896	658

Continuous Performance Sampling

- In most organizations, the number of standard minutes earned can be compared with the number of minutes actually worked and a performance index can be determined for each worker and for the department. This plan of labor control is widely used and is very effective in many situations.

- However, much work does not lend itself to direct measurement. The cycles may be long and varied, methods may not be standardized, and it is often difficult to obtain a count of the units of work completed. In such situations it is possible to obtain some control of labor by the use of work sampling.

Continuous Performance Sampling

- Continuous performance sampling can be carried on, and this can provide management with information concerning the work force such as:
  1. Percentage of time working
  2. Percentage of time out of department
  3. Percentage of time idle
  4. Average performance index while working
  5. Labor effectiveness factor (Item1xItem 4)

Procedure For Making A Work Sampling Study

1. Define the problem (state objectives + describe each element in detail).

2. Obtain the approval of the supervisor of the department and make sure operators and other people understand the purposes of the study.

3. Determine the desired accuracy.

4. Make a preliminary estimate of the percentage of occurrence of the activity or delay to be measured.

Procedure For Making A Work Sampling Study

5. Design the study
   - Determine the number of observations to be measured
   - Determine the number of observers
   - Determine the number of days or shifts needed to be studied
   - Make a detailed plan for taking the observations, such as the time and the route to be followed by the observer.
   - Design the observation form.

6. Make observations according to the plan. Analyze and summarize the data.

7. Check accuracy or precision of the data at the end of the study.

8. Prepare the report and state conclusions. Make recommendations if such are called for.

Determining Time Standards by Work Sampling

$$\text{Standard Time per piece} = \frac{\begin{pmatrix}\text{Total time}\\ \text{in minutes}\end{pmatrix} \times \begin{pmatrix}\text{Working time}\\ \text{in \%}\end{pmatrix} \times \begin{pmatrix}\text{Performance Index}\\ \text{in \%}\end{pmatrix}}{\text{Total number of pieces produced}} + \text{Allowances}$$

Example 3

Information	Source of Data	Data for One Day
Total time expended by operator (working time and idle time)	Time cards	480 min.
Number of parts produced	Inspection Department	420 pieces
Working time in per cent	Work sampling	85%
Idle time in per cent	Work sampling	15%
Average performance index	Work sampling	110%
Total allowances	Company time-study manual	15%

$$\text{Standard time per piece} = \frac{\left(\begin{matrix}\text{Total time}\\ \text{in minutes}\end{matrix}\right) \times \left(\begin{matrix}\text{Working time}\\ \text{in per cent}\end{matrix}\right) \times \left(\begin{matrix}\text{Performance index}\\ \text{in per cent}\end{matrix}\right)}{\text{Total number of pieces produced}} + \text{Allowances}$$

$$= \left(\frac{480 \times 0.85 \times 1.10}{420}\right) \times \left(\frac{100}{100 - 15}\right) = 1.26 \text{ minutes}$$

Figure 251 Data sheet and computation of standard time.

Example 4

DAILY SUMMARY					Computation of Average Performance Index
Performance Index	April 1	April 2	April 5	Total	
100	3	6	1	10	100 × 10 = 1,000
105	13	22	9	44	105 × 44 = 4,620
110	32	21	24	77	110 × 77 = 8,470
115	48	45	17	110	115 × 110 = 12,650
120	47	49	39	135	120 × 135 = 16,200
125	27	28	56	111	125 × 111 = 13,875
130	26	13	22	61	130 × 61 = 7,930
135	15	8	11	34	135 × 34 = 4,590
140	14	15	22	51	140 × 51 = 7,140
145	8	20	27	55	145 × 55 = 7,975
150	2	10	11	23	150 × $\frac{23}{711}$ = $\frac{3,450}{87,900}$
"Working" Observations	235	237	239	711	$\frac{87,900}{711}$ = 123.6
"Idle" Observations	5	3	1	9	
Total Observations	240	240	240	720	

Figure 252 Daily summary and computation sheet.

Example 4

Information	Source of Data	Data for Three-Day Period
Total time expended by operator (working time and idle time)	Time cards	13,650 min.
Number of parts produced	Inspection Department	16,314 pieces
Working time in per cent	Work sampling	98.7%
Idle time in per cent	Work sampling	1.3%
Average performance index	Work sampling	123.6%
Total allowances	Company time-study manual	15%

$$\text{Standard time per piece} = \frac{\left(\text{Total time in minutes}\right) \times \left(\text{Working time in per cent}\right) \times \left(\text{Performance index in per cent}\right)}{\text{Total number of pieces produced}} + \text{Allowances}$$

$$\left(\frac{13{,}650 \times 0.987 \times 1.236}{16.314}\right) \times \left(\frac{100}{100 - 15}\right) = 1.20 \text{ minutes}$$

Figure 253 Data sheet and computation of standard time.

Advantages of Work Sampling

1. Many operations or activities which are impractical or costly to measure by time study can readily be measured by work sampling.
2. A simultaneous work sampling study of several operators or machines may be made by a single observer. Ordinarily an analyst is needed for each operatör or machine when continuous time studies are made.

Advantages of Work Sampling

3. It usually requires fewer man-hours and costs less to make a work sampling than it does to make a continuous time study.

4. Observations may be taken over a period of days or weeks, thus decreasing the chance of day-to-day or week-to-week variations affecting the results.

Advantages of Work Sampling

5. It is not necessary to use trained time study analysts as observers for work sampling studies unless performance sampling is required. If a time standard or a performance index is to be established, however, then an experienced time study analyst must be used.

6. A work study may be interrupted at any time without affecting the results.

Advantages of Work Sampling

7. Work sampling measurements may be made with a preassigned degree of reliability.

8. With work sampling the analyst makes an instantaneous observation of the operatör at random intervals during the working day, thus making prolonged time studies unnecessary.

Advantages of Work Sampling

9. Work sampling studies are less fatiguing and less tedious to make on the part of the observer.

10. Work sampling studies are preferred to continuous time studies by the operators being studied. Some people do not like to be observed continuously for long periods of time.

Advantages of Work Sampling

11. A stop watch is not needed for work sampling studies. If an electronic data collector is used the results are shown on a computer printout.

Disadvantages of Work Sampling

1. Ordinarily work sampling is not economical for studying a single operator or machine, or for studying operators or machines located over a wide areas. The observer spends too much time walking to and from the work place or walking from one place to another. Also, time study, standard data, or predetermined time data are preferred for establishing time standards for short-cycle repetitive operations.

Disadvantages of Work Sampling

2. Time study permits a finer breakdown of activities and delays than is possible with work sampling. Work sampling cannot provide as much detailed information as one can get from time study.

3. The operator may change his/her work pattern upon sight of the observer. If this occurs, the results of such a work sampling study may be of little value.

Disadvantages of Work Sampling

4. A work sampling study made of a group obviously presents average results, and there is no information as to the magnitude of the individual differences.

5. Management and workers may not understand statistical work sampling as readily as they do the time study.

Disadvantages of Work Sampling

6. In certain kinds of work sampling studies, no record is made of the method used by the operator. Therefore, an entirely new study must be made when a method change occurs in any element.

Disadvantages of Work Sampling

7. There is a tendency on the part of some observers to minimize the importance of following the fundamental principles of work sampling, such as the proper sample size for a given degree of accuracy, randomness in making the observations, instantaneous observation at the preassigned location, and careful definition of the elements or subdivisions of work or delay before the study is started.