

Chapter 17

Work sampling

17.1 Principle of work sampling

Work Sampling is a technique to estimate the total time that various activities contribute to the job by taking an assigned number of observations at random intervals. A single observer can collect data on several activities at a time that are impractical or too costly to be measured by time study. This is shorter than production study that involves studying and recording of an operation for 100% of its duration. Work Sampling is hence faster and cheaper. Apart from establishing operational standard times, work sampling can effectively be used to determine production standards, machine and personnel utilization, job allowances, etc.

Originally started to observe the performance of operatives, work sampling has now been used effectively to measure operational times and productivity. It is based upon the laws of probability. A random sample is taken 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 not differ much from the characteristics of the group. Typically work sampling can provide information on

1. How much time of the working day during which workers or machines are producing.
2. How much time of the working day used up by delays. The reason for each delay must be recorded.
3. The relative activity of different workers and machines.

17.2 Production study vs. work sampling

Before understanding the principles and uses of work sampling, it is imperative to know something about production study, which involves the recording of all activities and delays that occur on a particular workstation by stopwatch time study right from the beginning of the shift to the end of the shift, or longer if necessary.

As cited in paragraph 17.1, work sampling and production study differ in the duration for which an operation is studied. This aspect can be understood better by comparing the following definitions.

17.3 Definitions on production study

Production study is a continuous study of relatively lengthy duration, often extending over a period of one or more shifts, taken with the objective of checking an existing or proposed standard time or obtaining other information affecting the rate of output.

The B S 3138 and also IS 6363.

17.4 Objectives of production study

1. To obtain data to help the management to take a decision on contingency, etc., allowances.
2. To identify the causes for downward trend of the output of a particular workstation.
3. To ensure that the observation and timing adequately covers all work contained in the job and that nothing has been omitted from the work specification.
4. To ensure that each and every activity that occurs during working period is not overlooked, with specific reference to the periodic delays which normally do not occur during the few cycles that are timed by time study.
5. To obtain a detailed account of a performance during a specified period.
6. To validate the standard and allowed times.
7. To assess if the relaxation allowance allowed is appropriate to the job.
8. To identify the avoidable and unavoidable delays as well as other ineffective times.
9. To check levels of output and investigate into unusual or unexpected changes in performance.
10. To establish the reason for different output rates during different times of the day. For example, it is a common notion than the output is higher in the morning than during the afternoon.
11. To validate the synthetic-data, formulae and values in the working situation.
12. As a routine checking, auditing and updating of the existing operational procedure, standard and allowed times etc.

17.5 What is work sampling?

On the other hand, work sampling, which is based upon the laws of probability, the observer keeps visiting a work spot at random intervals and notes down which element or operation is occurring. An end of the day he summarizes the number of the occurrences of individual

elements as a proportion of the total number of observations to indicate the overall percentage of each element.

17.6 Definitions on work sampling

Work sampling is a technique in which a large number of observations are made on a group of machines, processes and or workers. Each observation records what is happening at that instant and the percentage of the number of observations recorded for the particular activity or delay is a measure of the percentage of time for which the activity or delay occurs in the total cycle time.

BS 3138 and IS 6363.

Work sampling is the statistical technique for determining the proportion of time spent by workers in various defined categories of activity like setting up a machine, assembling two parts and idle time.

Wikipedia.

Work sampling is a method in which a large number of instantaneous observations are made at random time intervals over a period of time or a group of machines, workers or processes/operations. Each observation records what is happening at that instant and the percentage of observations recorded for a particular activity or delay/idleness is a measure of the percentage of time during which that activity or delay/idleness occurs.

www.yourarticlelibrary.com

Work sampling is a statistical technique used for predicting the total time consumed by an activity, in processes ranging from customer service and manufacturing to telemarketing. It relies on the observations made over a period to record what is happening at that instant, and the frequency at which one or more activities are being performed.

<http://www.businessdictionary.com>

Work Sampling, also called ratio delay study, is a technique of getting facts about utilization of machines or human beings through a large number of instantaneous observations taken at random time intervals. The ratio of observations of a given activity to the total observations approximates the percentage of time that the process is in that state of activity.

NPTEL, IIT Madras.

Work Sampling is a technique that discovers the proportions of total time that various activities contribute to the job by taking a relatively large number of observations at random intervals.

Auburn University.

17.7 Categories of work sampling

Work Sampling has three main categories:

1. Activity and Delay Sampling

Activity and Delay Sampling is the most common category, and is used 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

The purpose of performance sampling is to measure working time and non-working time of a person on a manual task, so as to establish a performance index for the person during his or her working time.

3. Work Measurement

Work sampling can also be used as a work measurement tool to time study several operations simultaneously, to obtain the preliminary time standard so as to select the tasks that should be given priority for time study.

17.8 History of work sampling

- Leonard Henry Tippett of Shirley University, UK, is considered as the father of Work sampling. During his study in British textile mills in 1927 to ascertain the duration and the reasons for the stoppages of the looms, and yarn breakage rates in cloth weaving, He applied statistics and noted that a large number of looms can be studied by making the observations at random. He called this 'snap-reading' method of observation that led to improved production efficiency and operative utilization. He subsequently developed the random numbers table, as well as the Fisher-Tippett distribution.
- R. L. Morrow of New York University, introduced it in US in the name of 'Ratio delay study' since it is basically applied if sample studies in ascertaining the ratio of the delay over the total available time.
- C. L. Brisley and H.L. Waddell later coined the word 'work sampling' in their article published in 1952, in 'Factory management and Maintenance'.

17.9 Why work sampling?

As can be seen from the above points, production study is to be adapted only in specific cases as and when needed. For normal cases of work measurement, especially for operations having shorter cycle times the usual stopwatch time study as explained in the previous paragraph is adapted. By selecting few cycles during the different parts of the day and averaging them serves more or less the same purpose of production study, at the same time

enabling us to time more operations in-one day as compared to a single operation possible by production study. In other words, the latter is an example of application work simplification to the work measurement job itself.

Further extension of this work simplification even for the stopwatch time study is work sampling, also called as activity sampling, which involves the estimation of the proportion of time devoted to several of an operation or activity over a certain duration of time by means of intermittent randomly spaced observations. It can tell what percentage of the working day, an operator is actually doing productive work, for how much time he spends for his personal needs or for how long he remains idle due to several specified reasons. For activities of very long duration an appropriate technique of work measurement is work sampling which takes only 1/20th of the time required for stopwatch study and gives the result within an accuracy of $\pm 2\%$.

Work sampling is effective in the following two situations.

- For long cycle operations like a maintenance gang working on a group of machines or general foundry operations. Here the emphasis is to establish the causes and time duration of the delays and other ineffective factors that occur during the course of the day than to set up production targets.
- For large groups of identical machines where the operations comprise of similar elements during the course of the day. A Typical illustration is the automatic loom shed in a textile weaving department where one man controls the operation of 12 or more looms. Here the machines work continuously unless they stop automatically due to some defect or other like snapping of the weft or warp yarn. The operator has to overview the working of the machine and when any machine stops, he has to go to the machine, rectify the defect and restart the machine. In this case we are not interested in the %age idle time for one machine, but the average occurrence of stoppage and idleness factor for all identical machines as a group.

17.10 Characteristics of work sampling study

The following factors need to be satisfied for conducting work sampling study:

1. The first and foremost is the non-repetitive work cycles.
2. The second requirement is a long cycle time, during which the observer would be able to record the occurrences of several events.
3. The third is the presence of multiple workers on a production line or assembly line or multiple operations performed by a single worker.
4. There must be enough time available (several weeks or more) to conduct the work sampling study. Since several operations/projects can be observed by work sampling at any time, unlike the time study, the overall time for studying all the operations would still be considerably less.

17.11 Objectives of work sampling

1. To estimate an avoidable delay time & for establishing allowances to standard time.
2. To estimate percentage utilization of machine tools.
3. To estimate percentage of time consumed by various job activities on the part of shop supervisors, engineers, inspectors, repairmen etc.
4. To obtain the results faster and with less expenditure of time and energy
5. To cross check the accuracy of the earlier work standards set by stop-watch time study.

17.12 Procedure for work sampling

The work sampling procedure consists of following three phases

A. *Preparing for work sampling*

1. Define the problem, determine the main objectives and identify each activity to be measured.
2. Estimate the measure of the output produced or the types of activities performed on the jobs that are studied, since our ultimate objective is setting work standards.
3. Obtain the approval of the supervisor of the department in which work sampling is to be performed.
4. Ensure that all the persons connected with the study; understand the objectives and the procedure adapted by you in conducting the study, and that they accept the frequent visits of the work study engineer.
5. Select of train the work sampling personnel.
6. Make a detail plan for taking observations
7. Determine the time period during which the study will be conducted. Define the starting and stopping points for the study
8. Decide on the defined accuracy limits for the ultimate results

B. *Performing work sampling*

1. Conduct a pilot study to
 - estimate the approximate percentage accuracy of activity
 - estimate the required number of observations for the desired accuracy set using the formula illustrated in paragraph 17.15
2. Based on the random number tables, decide upon the intervals and periods of observations.
3. Design the actual study and the observation form.
4. Using this data obtained from pilot study and the estimated value of p , calculate the number of observations to be made.
5. Observe the activities and record the data. It is better to make the all the observations from the same location
6. Verify any discrepancy with the supervisor or foreman
7. Summarize the data at the end of the study.

C. Evaluating and presenting results of work sampling

1. Determine the percentages of occurrence of each activity.
2. Analyze the causes for delays which are higher than normal.
3. Propose recommendations and get them implemented.
4. Reconduct work sampling as above for the new method.
5. Compare and evaluate the new and old methods.
6. Present an effective report.

17.13 Statistical theory behind work sampling

Work sampling relies upon the theory of statistical sampling and probability. Theory of normal frequency distribution and confidence level too are associated very much with- work sampling.

The statistical theory of sampling explains that adequate random samples of observations spread over a sufficient period of time can give accurate picture of the actual situations in the system. Approximately 500 observations produce fairly reliable results in most cases, though the actual number of observations to be made depend upon the three factors explained below and incorporated in the formula per paragraph 17.15:

- a. The probability of the occurrences of an element. In our case it is the percentage of idle time.
- b. The confidence limits with which we want to say that the sample represents the total population or the actual situation.
- c. The percentage of error that can be allowed in the study or in other words the accuracy to which you want the result.

Fig. 17.1 below gives a typical, normal curve for which most random observations are expected to conform to from which you can see that the area between $x \pm 1\sigma$ covers 68% of the area under the whole curve or 68% of the samples would fall within these limits. In other words, we can say with

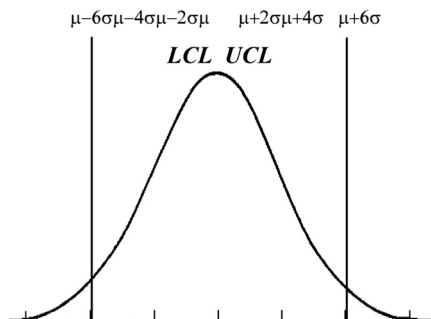


FIGURE 17.1 A typical normal curve and the representation of limits.

68% confidence that the observations between $x \pm 1\sigma$ would conform to presumed situation. This is called the confidence limits.

Table 17.1 below indicates the confidence limits for other values. Similarly, a confidence level of 95.45% signifies that the work study engineer is sure that in 95.45% of the random observation will represent the true factors.

TABLE 17.1 The relationship between value and the confidence limits.

Std. deviation	Confidence interval	Confidence level %	Error level %
0.318 639σ	0.318 639σ	25%	75%
0.674490σ	0.674490σ	50%	50%
0.994458σ	0.994458σ	68%	32%
1σ	1σ	68.2689492%	31.7310508%
1.281552σ	1.281552σ	80%	20%
1.644854σ	1.644854σ	90%	10%
1.959964σ	1.959964σ	95%	5%
2σ	2σ	95.4499736%	4.5500264%
2.575829σ	2.575829σ	99%	1%
3σ	3σ	99.7300204%	0.2699796%
3.290527σ	3.290527σ	99.9%	0.1%
3.890592σ	3.890592σ	99.99%	0.01%
4σ	4σ	99.993666%	0.006334%
4.417173σ	4.417173σ	99.999%	0.001%
4.5σ	4.5σ	99.9993204653751%	0.0006795346249%
4.891638σ	4.891638σ	99.9999%	0.0001%
5σ	5σ	99.9999426697%	0.0000573303%
5.326724σ	5.326724σ	99.99999%	0.00001%
5.730729σ	5.730729σ	99.999999%	0.000001%
6σ	6σ	99.999998027%	0.000001973%
6.109410σ	6.109410σ	99.9999999%	0.0000001%
6.466951σ	6.466951σ	99.99999999%	0.00000001%
6.806502σ	6.806502σ	99.999999999%	0.000000001%
7σ	7σ	99.9999999997440%	0.000000000256%

It may be noted that this σ value is different in concept from sigma level (like six sigma level) as used in TQM Chapter 24 of the book, Total Quality Management, Key Concepts and Case Studies, referred under Further Reading for better clarification.

Let us presume that the work study engineer takes 25 rounds of the machine shop in a day to observe the operator 'x' and finds that.

- 15 times he is working on the machine
- 4 times he is setting tool or cleaning the machine
- 3 times he is not doing anything
- 3 times he has gone for his personal needs.

This shows that the worker spends 60% of his time in actually working over machine and for 12% of the total time he is idle, etc. These facts can be confirmed by conducting more number of observations.

17.14 Random timing

We have seen, in the earlier paragraphs that random sampling allows every unit or part of the total population on equal chance of being included in the sample. That is the parameters of the sample chosen at random are expected to be same as those of the whole population. In the work sampling, the randomness is in the timing of observations, so that the readings taken at these intervals represent the actual situation. To avoid individual bias, a pre-prepared list of random tables can be referred to. Nevertheless in these days of computerized data processing you can prepare your own random tables. The following procedure is suggested for the use of these random tables depending upon the number of observations you want to make and the time available for you to complete all the observations.

1. Choose the numbers in order they appear in the table or every alternative number or every fifth number etc., depending upon the total observations you want to make, say 22, 60, 75, 2, 90, 48, 36, 42, 99, 55, 10, 17, 52, 88, 26.
2. Arrange these numbers in ascending order, i.e. 2, 10, 17, 22, 26, 36, 42, 48, 52, 55, 60, 75, 82, 88, 90, 99.
3. Depending upon the total time available with you before which you have to complete the observations and the range of these random numbers assign a time value for the unit. For example, if the number range between 0 to 100, and you have to complete talking 15 observation in a shift of 400 minutes assign a value of 4 minutes for each unit. That is the observations will be at 8, 40, 68, 88, 104, 144, 192, 208, 220, 240, 300, 328, 352, 360 and 396 minutes after the start of the study say 8:00 a.m.

By using the random tables as above, the personal bias in choosing the time of each visit can be eliminated. Also, if the worker knows the definite

time of his next visit, he might deliberately feign productive time at that time, pushing all unproductive elements to the non-visit periods. This will naturally give distorted results.

17.15 Number of observations to be made

From statistics, the accuracy of the study is given by

From this we can calculate n , the number of observations as

$$n = \frac{pq}{\sigma_p^2} \text{ or } \frac{p(1-p)}{\sigma_p^2}$$

17.16 Use of nomographs for determining sample size

Other methods for finding one of observations are by use of nomographs, also called nomograms or alignment charts.

A nomograph is defined as a graph, usually containing three parallel scales graduated for different variables so that when a straight line connects values of any two, the related value may be read directly from the third vertical line at the point intersected by the line.

For example, if the percentage of occurrence during the initial study is 5.5% and the accuracy needed is 98.1%, then the no. of observations to be made are 620 at 95% confidence limits, as illustrated in [Fig. 17.2](#).

17.17 Advantages of work sampling

- (a) It involves much less cost compared to stopwatch time study.
- (b) Does not require the analyst to continually observe the job.
- (c) It can be performed with much less training.
- (d) It can be used for long operations, which are almost impractical to be measured by stop watch time study.
- (e) Very advantageous for timing group activities.
- (f) It doesn't need any timing device like stopwatch or micrometer, etc.
- (g) Even if the study gets interrupted in between, it does not introduce any error in the results.
- (h) Observations can be made within the desired accuracy.
- (i) Large number of observations extended over days or weeks reduces the influence of day to day fluctuations on the results.
- (j) It can increase efficiency by uncovering the sources of delay.

17.18 Limitations of work sampling

1. It is uneconomical and less accurate, both as regards time and money to study activities of short duration by work sampling.

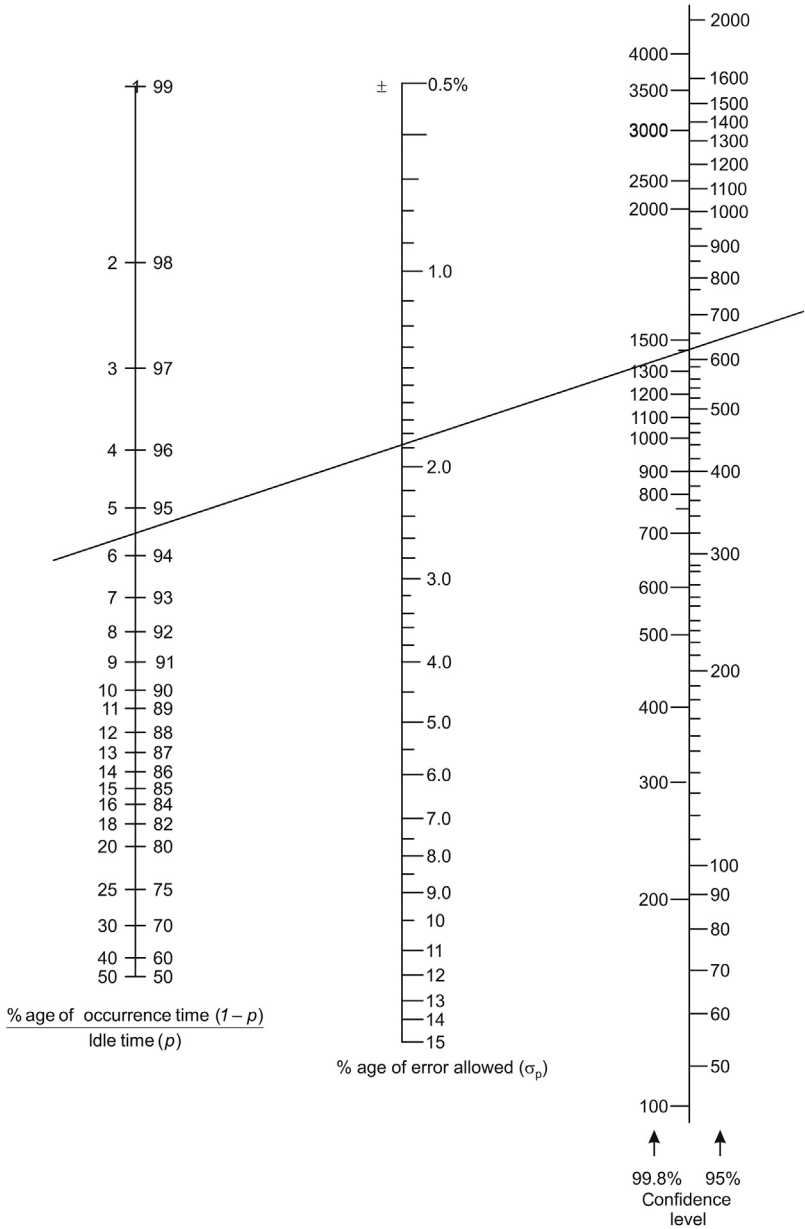


FIGURE 17.2 A nomograph. Courtesy I.L.O.

2. It is also uneconomical if only one worker or one machine is to be studied.
3. It does not break the job into elements and hence does not provide element details, as completely as time study.
4. It does not assist in the improving of work methods.
5. It normally does not account for the speed at which an operator is working.
6. Workers may not understand the principles of work sampling and hence may not trust it.
7. Observations, neither random nor sufficient in number may produce inaccurate results.
8. Can yield biased results if observer does not follow random pattern.

17.19 Applications of work sampling

To summaries, we can cite the applications of work sampling as under

1. To determine the working and idle times of men and machines.
2. To time long duration activities which are regular/irregular or frequent/infrequent.
3. To identify unwanted material handling don/ in day.
4. To estimate allowances for unavoidable delay.
5. To describe resources utilizing pattern.
6. For the purpose of cost control accounting.
7. To estimate the percentage utility of inspectors and time standards for indirect labor cost.
8. Very useful for stores, hospitals, ware housing, offices, farm work, repair and maintenance work in textile mills, machine shop, etc.
9. It is preferred when the cost of using other work measurement technique of timing a job appears to be great.

17.20 Performance sampling

This is a work sampling process, wherein the observer indicates the rating of the operative at the time of the observation on a suitably designed format and evaluates the readings using this rating factor. This will present a more accurate picture of the percentages of occurrences.

17.21 Computer software for work sampling

There are several software available for data entry and analysis of the elements performed during the sampling rounds. Most of these can also be loaded on to smart phones for facilitating on the field studies. Some popular software are cited below.

1. WorkStudy +

WorkStudy + is ideal for any type of data sampling, including fixed and random interval sampling. With a built-in sampling timer. WorkStudy + will automatically alert users when it is time to collect the next sample.

2. PATHSoft

PATHSoft was developed by South Eastern Louisiana University, PATH implying Posture, Activities, Tools, and Handling methodology. In addition to the web-based portion, this software has a Windows Mobile local application for use with Personal Digital Assistants (PDAs) and other mobile devices.

3. laubrass' UMT Plus software

This software possesses random study and multi-study features of UMT Plus to create performance standards for traditional time-work positions.

4. The Work Sampling System

The Work Sampling System is a curriculum-embedded, authentic performance assessment for teachers to use to assess young students' development in multiple domains. The program features updated content, based on Common Core and state early learning guidelines and current research in the field of early childhood education.

17.22 Conclusion

As stated in the synopsis, Work sampling is a process, where many instantaneous observations made at random time intervals over a period of time would yield fairly accurate time standards which can substitute the laborious process of work measurement. This is based on the theory of probability. Hence it is essential for us to understand how the theory of probability would lead to the success of work sampling, as explained in this chapter.

Criteria questions

1. Distinguish between Work Measurements. (17.2)
 2. What are the Objectives of Production Study? (17.4)
 3. Distinguish between Activity and Delay Sampling and Performance Sampling. (17.7)
 4. Trace the History and Development of Work Sampling. (17.8)
 5. Enumerate the Requirements of Work Sampling. (17.10)
 6. Discuss the Procedure for conducting Work Sampling. (17.13)
 7. Why is it important to make sure that Workers have understood the Purpose of, and accept the Frequent Visits? (17.13)
 8. Why is it necessary to Time the Visits at Predetermined Random intervals and not at Regular Periods? (17.15)
 9. How do you determine the Number of observations to be made for a Particular Operation? (17.16)
 10. What are nomographs? How they are useful in Work Sampling? (17.17)
 11. What are the Limitations of Work Sampling? (17.19)
 12. Cite some of the Computer Software available for Work Sampling. (17.22)
-

Further reading

1. Barnes R. *Motion and time study*. 7th ed. 1980.
2. Kiran DR. *Total quality management, an integrated approach*. BSP; 1963.
3. Kiran DR. *Production planning and control, a comprehensive approach*. BS Publications; 2018.
4. Brisley CL. Work sampling. In: Maynard. editor. *Industrial engineering handbook*. 3rd ed. McGraw.
5. Groover MP. *Work systems and methods, measurement, and management of work*. Pearson Education International; 2007.
6. Sheth V. *Industrial engineering methods and practices*. Penram International Publishing; 2000.
7. Browker A, Liebermann G. Industrial statistics. In: Ireson WG, Grant EL, editors. *Handbook of industrial engineering and management*. Prentice Hall; 1971.
8. Tsai W-H. A technical note on using work sampling to estimate the effort on activities under activity-based costing. *Int J Prod Econ* 1996.
9. http://www.southeastern.edu/acad_research/depts/iet/news/archive/drs_yuan_and_alkadi.html.
10. www.laubrass.com/umtplus.
11. www.umtproducts.com/casestudies/work-measurement-reviews/retail-productivity.