Mechanical Engineering

Industrial Engineering

Comprehensive Theory

with **Solved Examples** and **Practice Questions**

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CHAPTER 07

Work Study

7.1 INTRODUCTION

- Work study is the investigation, by means of consistent system to attain the best possible use of available men, machine, materials, money and time. Total concept of the work study is concentrated upon the answers of following two questions.
  (a) How should a job be done? How a job should be done?
  (b) How much time a job should take for completion?
- The answer for the first question is method study while the answer of the second question is time study and work measurement. Infect method study and the time study are not to be treated as two different parts of the work study and are very much inter-linked. However for the case of understanding, the work study is often classified into two parts as time study and method study as shown in Figure 7.1. Time study with its extension is known as work measurement whereas method study is sub-divided into two groups as motion study and micro motion study. The motion study has extended to the motion economics while micro motion study has led a way to ergonomics.
- Classifications of Work Study

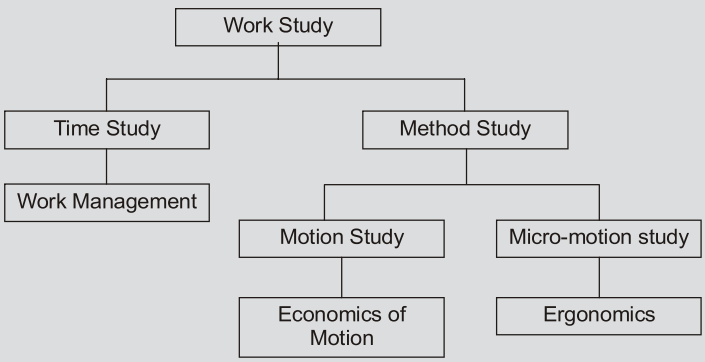


Figure 7.1 Classification of Work Study

7.2 Method Study

Method study is a systematic and scientific evaluation of existing and proposed plans and performance of a work and evaluation of improvement through analytical process of critical examination. This is a broad investigation for improvement of total department, layout of machines, equipment, flow of materials and movement of men. Method study has two levels of its application. These are:

(a) Motion study, and

(b) Micro-motion study.

- **Motion Study:** This is more detailed investigation of individual operation or operator and layout of materials, parts or tools around a working bench or machine, use of jigs, fixtures and consumables to perform the job effectively. The study of environment, body postures, gestures, the noise level, the temperature, the pressure, the humidity around the workplace are the major concerns of motion study which are now known as 'ergonomics'.
- **Micro-motion Study:** This is the most detailed investigation of the movements of hands, arms, limbs, legs, head, etc. while performing the job. Motion pictures, cameras, filmed records, etc. are a few tools used to study the micro-motions of a specified job.
- **The basic procedure of method study consists of the following steps:**
  (a) Define the problem and select the work to be taken for the study.
  (b) Record all the relevant facts about present method.
  (c) Examine the facts critically and impartially.
  (d) Develop the most practical, economical and effective method which will satisfy the three pillars viz. economical, technical and human factors.
  (e) Define the new and improved method so that the method can be identified and implemented.

Method study can be applied to layout, working conditions, movements, quality standards, designs, tools and equipment and material handling which may be detected to achieve the improvements either in short term or in long term benefits.

Thus method study is defined as follows (according to International Labour Organisation).

- *The systematic recording and critical examination of existing and proposed ways of doing a work as a means of developing and applying easier and effective method and thereby reducing the cost.*

7.2.1 Objective of Method Study

The method study is conducted with a main focus on the following objectives

(a) To bring improvement in process or procedure.

(b) To bring improvement in work place, workshop, working environment, layouts, etc.

(c) To bring economy in use of human effort and thereby enhance the human efficiency and productivity.

(d) To reduce unnecessary fatigue.

(e) To increase human comfort while doing work.

(f) To set-up better physical working conditions.

(g) To explore the ways for effective use of materials, tools machine, men and their movements.

NOTE

The standard procedure consists of the following six steps:

(a)	Select	(b)	Record
(c)	Examine	(d)	Develop
(e)	Install	(f)	Maintain

These are briefed out in the following paragraphs. (Made Easy Students may remember these with an acronym **SREDIM**, made of first letters of the words, which means 'to stab'.)

(a) Select

- Selection of problem is not as simple as one can think of. The problem identification involves a deep understanding into the methods and procedures followed to produce the product. However, industrial engineers have been provided with certain guidelines in selecting the problem and the tools for problem solving. These are given below:
- **The Problem:** The problem is selected from the area or process where least yield is resulting or where loss of output is felt. The problem must be selected in such a way that it should be possible to solve and would get a feasible solution. A problem, which cannot be reduced to any solution and impracticable, should not be selected. For example, trying to find a generator which can start without external power and without any power loss is impossible.

  Also the problem selected should be as small as possible. Selection of a problem of large volume, which involves many people, can only become a mess. The problem selected should be defined precisely and distinctly.
- **The Man:** Often, to solve the problem, the industrial engineer requires selecting an operator who can perform the modified method for defining the task and time study. The operator selected should be representative, i.e. the one who is selected should resemble to the group and normal in all respects such as efficiency, behaviour, skill, knowledge, etc. He should neither be highly skilled nor be unskilled. He should be neither highly efficient nor very low efficient and so on. He should have known all the parameters and phases of work. He must have willingness to work. He should be explained about the task, related job knowledge and concepts. He should be able to convince his co-workers with his achievements.
- **The Machine:** Like the selection of man, the engineer conducting method study, needs to select a machine also to take a decision on target fixation. The machine so selected should neither be new nor be old but in good operating conditions. It is better if the study is conducted on several machines to avoid unilateral decisions. The machines should be accurate and should repetitively give some results (precision) with a good process capability.
- **The Material:** Material with good quality and specified properties should be provided.
- **The Working Conditions:** The method study should be conducted at various combinations of working conditions ranging within ergonomically specified ranges. Also the experiments should be carried out at different times of a working day and different days of a month and at different seasons if required before standardising the methods.

(b) Record

- After selecting a particular task for study, it is essential to record the relevant facts regarding different processes or procedures, inspection parameters, transport constraints and various basic resource requirements and availabilities. An effective recording methods, charts and diagrams can help the decision quickly, easily, correctly and timely. Various charts available and in common use are explained in two categories as Type-A and Type-B as follows:

  Chart

  Type-A: These charts show the process required by the task as per their sequence.
  - Out line process chart
  - Flow process chart-man type
  - Flow process chart-material type
  - Flow process chart-machine type
  - Two handed process chart

Type-B: These charts show the process on time scale according to their sequence.

- Multiple activity chart
- SIMO chart
- PMTS chart

Apart from the above charts, there are a few diagrams seldom used in work-study. They are:

Diagrams : Flow diagram
String diagram
Cycle graph
Chronocycle graph
Travel chart
Rel chart

A brief explanation of these charts is given at the end of this unit.

(c) Examine

- After proper recording of the data, it is now important to examine these facts critically. All if s and but's could be brainstormed and some conclusions are to be drawn. These conclusions should be evaluated thoroughly from all the angles to choose best alternative. The pros and cons of each alternative should be written and a comparison chart is to be prepared if there are more than one good alternative by choosing suitable parameters for rating.

(d) Develop

- Develop the most efficient alternative with high degree of accuracy. Measurements should be made impartially and see that there will not be any human errors while developing the method. It is very important to consider Economic, Technical and Human aspects during developing activity. The method should be clearly defined after developing it. Also the amount of job involved arra standard should be calculated.

(e) Install

- Prepare an implementation plan and install the new method. Choose a suitable period of time to watch the progress and efficiency of the method. It has been often reported by the industrial engineers about the resistance from employees to the new method. No doubt, the 'static friction is definitely more than dynamic friction. So also the human reactions for any new thing. The records and comparison charts will certainly become the useful tools to convince and authenticate the new method.

(f) Maintain

- The final step of method study is in fact the most difficult part, to implement and maintain. The progress is to be recorded time to time and evaluated in suitable intervals. After a sufficient number of production runs and test readings, it is to be declared or standardised. However, it is essential to gain the acceptance from "various supervisors, workers involved (sometimes even from union) and management and the work place supervisors are to maintain the new method thereafter.

7.3 Micro-Motion Study

- It sometime becomes necessary to analyse the motions precisely and closely with a view that the unnecessary motion could be eliminated. It is worthwhile to perform such exercise on short cycles of movements, where the hand movements will be done , thousands of times, e.g. assembly of certain electronic parts, packing, counting, etc. This study is known as Micro-Motion Study.

- All the movements are grouped up into certain common motions and are symbolised. These movements are called Micro-motions and the symbol given to represent such movement (micro-motion) is known as Therblig (Gilbreth spelt reversely). These micro-motions are the outcomes of studies done by Frank Gilbreth and his wife Lillian Gilbreth. They also have given the short forms pf letters or notations for these micro-motions. All together, there are seventeen (originally sixteen) micro-motions identified by Gilbreths. These are given in Table 7.1.
- In fact, originally sixteen therbligs were used in the micro-motion study. Out of the sixteen, thirteen are said to be active and three (AD, UD and R) are inactive. Later the seventeenth therblig PLAN (Pn) was introduced, which was also inactive. In fact, Gilbreth introduced these to analyse the hand, finger and eye motion, but later, Bames changed the concept and applied them to analyse the motions of body members also.

Table 7.1 Therbligs

Sl. No.	Activity	Symbol	Therblig	Colour	Explanation
1.	Assemble	A		Violet	Putting the objects together
2.	Disassemble	DA		Light violet	Separating different parts of the assembled unit
3.	Avoidable delay	AD		Lemon yellow	A delay within operator's control
4.	Unavoidable delay	AUD		Yellow	A delay on which operator has no control
5.	Transport loaded	TL		Green	Moving an article from one place to another
6.	Transport empty	TE		Olive green	Moving (a body member, say hand) empty
7.	Search	Sh		Black	Hunting for an object
8.	Plan	Pn		Brown	Mental reaction before action
9.	Rest	R		Orange	An allowance, idleness or pause to overcome fatigue incurred during previous work
10.	Position	P		Blue	Turning to line up, orient or change position
11.	Find	Sh		Grey	Mental reaction at the end of search
12.	Inspect	I		Burnt ochre	Examining an object for its quality
13.	Preposition	PP		Pale blue	Locating an article in predetermined position so that it is ready for use
14.	Grasp	G		Red	Taking hold of something
15.	Use	U		Purple	Manipulating or causing a tool to do its function
16.	Hold	H		Gold ochre	Retention (after grasp)
17.	Select	S		Light gray	Choosing one object from amongst many
18.	Release load	RL		Carmine red	Releasing an object

7.4 Charts and Diagram

7.4.1 Charts

(i) Flow Process Chart

- It is the chart which sets out sequence of flow of a product, man or machine or material by recording all events in its process, in terms of appropriate symbols.
- ASME defines the flow process chart as "a graphic representation of the sequence of all operations, transportations, inspections, delays and storages occurring during a process or procedure and includes information considered desirable for analysis such as time required and distance moved".

(ii) Two-hand Process Chart

- This chart is used to study the motions of two hands or limbs of worker and bring out the effectiveness and hence the efficiency.
- It is defined as "a process chart in the activities of a worker's hands or limbs are recorded in relationship to each other".
- This technique is widely used for micro-motion study where the jobs with short and complicate work-cycle can easily be studied.

(iii) Multiple Activity Chart

- All the above charts the chart can tell us about only one of resources like either a worker or an equipment or material, etc. But the relation between a man and machine or man and material, etc. are not known. The multiple activity chart can give all these in a very compact manner. This chart enables the industrial engineer to study whether any unnecessary waiting times can be eluded.

  The multiple activity charts are prepared in one of the four ways as follows :

  (a) One man – one machine chart
  (b) Two men – one machine chart
  (c) One man – two machine chart
  (d) Two or more men – one or more machine chart

(iv) Rel Chart

- Its full name is relationship chart. Here the relationship between various departments can be understood by the help of which the layout of departments can be made optimally so as to reduce the distance of motions by keeping highly related departments nearer. This relationship is usually based on the number of movements among the departments and often makes use of travel chart for reading the number of motions. The rel chart uses the notations as vowels A, E, I, *O*, U and one consonant *X* for representing the relations. The relations are

  A for **A**bsolutely necessary
  E for **E**ssential
  I for **I**mportant
  O for **O**rdinary
  U for **U**nimportant
  X for **N**o relation

  A relation chart is shown in Figure 7.2
- It is to be read by the cell intersected by paths drawn from respective departments. For example, relation between production and planning from the below chart can be read as 'A', i.e., absolutely necessary.

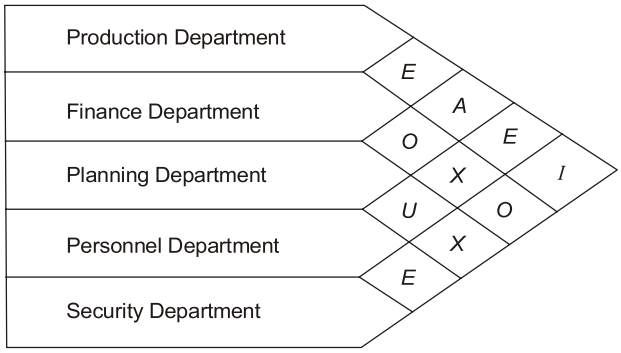


Figure 7.2 Rel Chart or Relationship Chart

7.4.2 Diagrams

A diagram is more powerful tool of recording as it looks attractive, eye catching and is easy to understand than charts, even without any prerequisite knowledge of techniques or the process. The most popular diagrams used in work-study are briefed out hereunder.

(i) **Flow Diagram:** A plan of work area on scale with the accurate location of facilities is a flow diagram. The symbols used for flow-chart can also be used here. An example is as shown in Figure 7.3, which explains the serving dinner in a hospital ward, in two methods, by proposed method distance saved is about 54 percent (refer ILO - Introduction to Work Study).

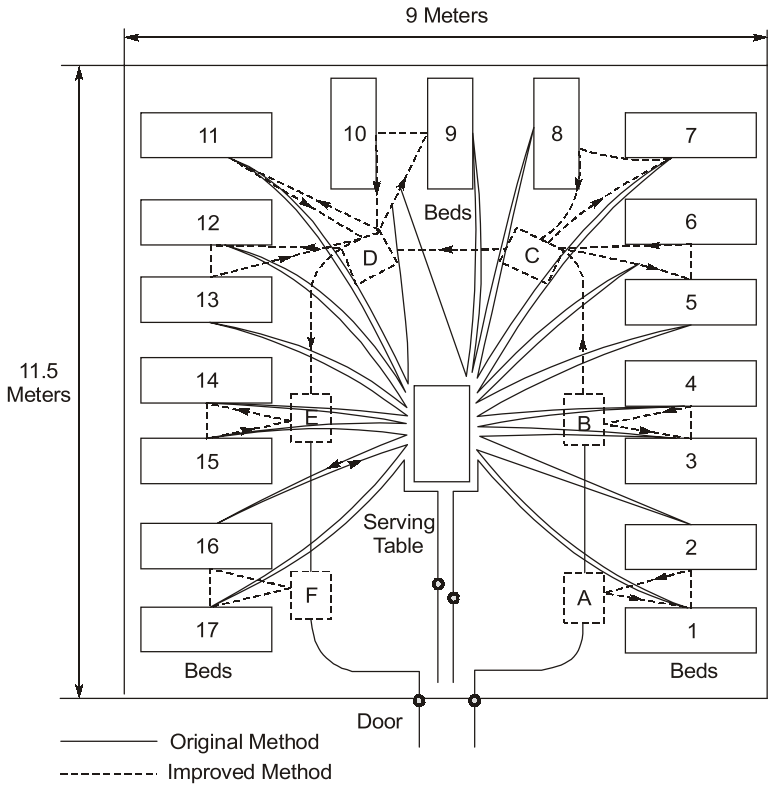


Figure 7.3 Flow Diagram

(c) Remunerate each worker with large pay when he accomplishes his task.

(d) Make sure that when a workman fails, he is the loser thereby.

Thus time study is basically a work measurement technique and is defined as follows (according to International Labour Organisation).

- Time study is a work measurement technique for recording the times and rate of working for the elements of a specified job carried out under specified conditions and for analysing the data so as to obtain defined level of the performance.

7.5.1 Work Measurement

Work measurement is very difficult owing to diversified set of reasons. Perhaps the measurement of human factors is the most difficult factors of all. The human measurement particularly with a balance between work content and labour time is beyond the scope of scientific methods due to various physiological factors such as frustrations, monotony, boredom, anxiety, willingness to work, skill, will power, confidence, attitude and many more. Apart from these there will be the influence of physical and environmental factors like temperature, dust, noise, vibrations, pressure, humidity, etc. keeping all these in normal or acceptable conditions some methods have already been laid down for measurement of-any type of work. The work measurement is generally followed by method study by which a clearly defined and developed method is laid down.

All that credit goes to the pioneering work of Fredrick Winslow Taylor for his methods of work measurement and time study. He suggests to split the activity into elements and assign the time to it by repeated experimentation. Thus time study provides a reliable data for establishing consistent standard performance and elimination of the ineffective time from the production cycle time.

As Defined

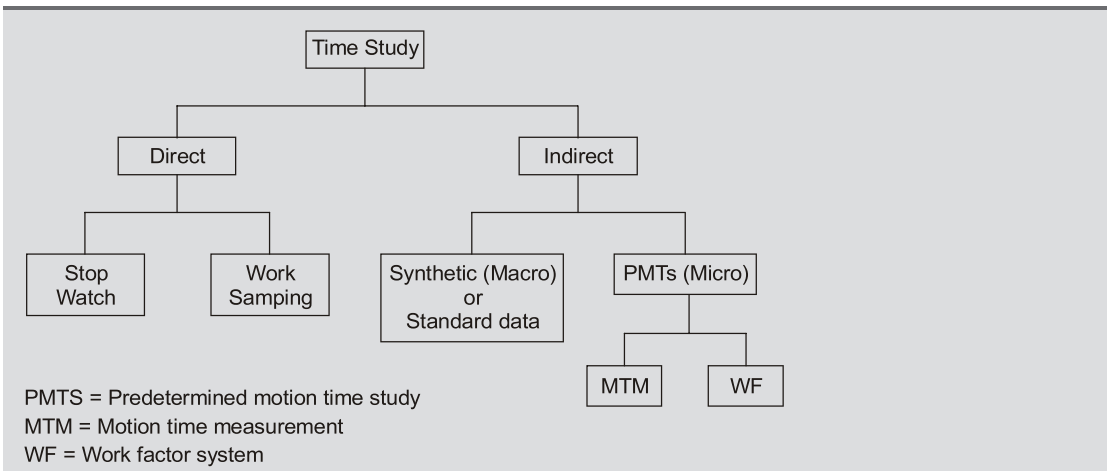
- *Work measurement is the application of techniques designed to establish the time for a qualified Worker to carry out a specified job at a defined performance.*

  and,

  Time study is a work measurement technique for recording the times and rate of working for the elements of a specified job carried out under specified conditions/and for carrying out the job at a defined level of the performance.

  (Definition according to ILQ),

- Classifications of Time Study



7.5.2 Steps in conducting time study:

Step 1

- Record all the necessary information about the job such as product information (name of the product, material, quantity, quality requirements), process information (location of work place, process description, tooling, jigs and fixtures, layout, speeds and feeds, settings, rate of productions), information about operator (name, competence, skill, education, experience, etc.), information regarding working conditions (temperature, pressure, humidity, economical factors, human factors, lighting, etc.

Step 2

- Record the method by breaking down the operation into elements to ensure most effective method and sequence of the motions.

Step 3

- Record the skill and competence of the operator to ensure that 'qualified' worker is allowed to work that is to be timed. A 'qualified worker' is one who is neither very skilled nor unskilled but an average; neither highly experienced nor inexperienced, and so on, so that the measurement is made at any normal level.

Step 4

- Record the time for each element of the operation with the help of stopwatch or by any other time measuring device or formula. The process of time taking of the same element may be repeatedly for pre-determined no. of times and the rate of the worker is to be compared with preconceived concept of standard rating.

Step 5

- Compute the basic time for each element by taking the average and then compute the normal time with the formula;

  Normal time = Basic time x Rating factor

Step 6

- Determine the allowances to be added to the normal time to determine the standard time by using the formula;

$$\text{Standard time} = \text{Normal time} \times \text{Allowances Factor}\left(= \frac{100}{100 - \text{allowance in \%}}\right)$$

NOTE : Rating factor is applied only to manual controlled operation and is never applied for machine component. For Machine Normal Time = Operation Time

Example 7.1 A job has been sub-divided into five elements. The time for each element and respective rating are given below:

Element Number	Observed Time	Rating Factor %
1	0.7	80
2	0.8	100
3	1.3	120
4	0.5	90
5	1.2	100

Calculating the normal time and standard time for each element and for the job if the allowance is 15%.

Solution:

For Element 1

$$\text{Normal Time} = \text{Observed time} \times \text{Rating Factor}$$

$$= 0.7 \times \frac{80}{100} = 0.56 \text{ min.}$$

$$\text{Standard Time} = 0.56$$

$$\text{Allowance factor} = 0.56 \times \left(\frac{100}{100-11}\right) = 0.56 \times \frac{100}{89} = 0.629$$

For Element 2

$$\text{Normal Time} = 0.8 \times \frac{100}{100} = 0.8 \text{ min.}$$

$$\text{Standard Time} = 0.8 \times \frac{100}{100-15} = 0.94 \text{ min.}$$

For Element 3

$$\text{Normal Time} = 1.3 \times \frac{120}{100} = 1.56 \text{ min.}$$

$$\text{Standard Time} = 1.56 \times \frac{100}{100-15} = 1.835 \text{ min.}$$

For Element 4

$$\text{Normal Time} = 0.5 \times \frac{90}{100} = 0.45 \text{ min.}$$

$$\text{Standard Time} = 0.45 \times \frac{100}{100-15} = 0.529 \text{ min.}$$

For Element 5

$$\text{Normal Time} = 1.2 \times \frac{100}{10} = 1.2 \text{ min.}$$

$$\text{Standard Time} = 1.2 \times \frac{100}{100-15} = 1.41 \text{min.}$$

Normal Time of the job (total) = 4.57 min.
Standard Time of the job (total) = 5.343 min.

Example 7.2 The observed time for an element is 1.2 minutes. The pace rating for the element is 120% and job difficulty is found to be 30%. Find Normal Time of the element. Also find standard Time at an allowance of 10%.

Solution:

$$\text{Base Time} = 1.2 \times \frac{120}{100} = 1.44 \text{ min}$$

$$\text{Normal time (NT)} = 1.2 \times \frac{120}{100} \times \frac{130}{100} = 1.872 \text{ min}$$

$$\text{Standard Time} = 1.872 \times \frac{100}{100-10} = 2.08 \text{ min.}$$

Objective Brain Teasers

Q.1 Match **List-I** (Charts) with **List-II** (Details) and select the correct answer using the codes given below the lists:

List-I

A. Multiple activity chart
B. SIMO Chart
C. String diagram
D. MTM

List-II

1. Work factor system
2. Movement of material
3. Motion analysis
4. Working and idle time of two or more man/machines

Codes:

	A	B	C	D
(a)	4	2	1	3
(b)	1	2	4	3
(c)	4	3	2	1
(d)	1	3	4	2

Q.2 Area under standard normal curve within range, mean ± 2 standard deviation, is about

(a) 99.5% (b) 99.7%
(c) 95.5% (d) 68%

Q.3 Which one of the following technique is used for determining allowances in time study?

(a) Acceptance sampling
(b) Linear regression
(c) Performance rating
(d) Work sampling

Q.4 Match **List-I** (Activity name) with **List-II** (Symbol) and select the correct answer using the codes given below the lists:

List-I	List-II
A. Transportation	1. *D*
B. Storage	2. ∇
C. Delay	3. ⇒
D. Operation	4. *O*

Codes:

	A	B	C	D
(a)	1	2	3	4
(b)	3	4	2	1
(c)	3	2	1	4
(d)	2	1	4	3

Q.5 Which of the following is not correct for Taylor's scientific management?

(a) Taylor's scientific management is used to increase efficiency
(b) Primary objective function of the Taylor scientific management is maximum prosperity
(c) Primary objective function of the Taylor scientific management is minimum prosperity
(d) Taylor's scientific management reduces 'rule of thumb'.

Q.6 Match **List-I** (Therblig) with **List-II** (symbol) and select the correct answer using the codes given below the lists:

List-I	List-II
A. Grasp	1. 
B. Use	2. 
C. Hold	3. 
D. Release load	4. 

Codes:

	A	B	C	D
(a)	1	2	3	4
(b)	2	1	4	3
(c)	2	4	1	3
(d)	1	2	4	3

Q.7 The time study data of a lathe in a factory during a calendar month is given below :

Total working hours = 400
Total maintenance hour = 100
Total hours of actual work = 240

The percentage utilization of the equipment is _____ %.

Q.8 The standard time of an operation has been calculated as 15 min. The worker was rated at 80%. If the relaxation and other allowance were 25% and provided on the standard time, then the observed time will be _____ minutes.

Q.9 A machine is used for turning operation and it takes 30 minutes to machine the component. Efficiency of the machine is 80% and scrap is 25%. The desired output is 1200 pieces per week. Considering 40 hours per week and 50 weeks in a year. The number of machines required in a year _____.

Q.10 In a steady to estimate the idle time of a machine, out of 100 random observations the machine is found idle on 40 observations. The total random observations required for 95% confidence and ±2.5% accuracy are _____.

Q.11 In a work study, the following observation were made:
Observation of machines while working = 3000
Observation of machines while idle = 2000
Calculate the accuracy for 95% confidence level.

Q.12 The observed time of an operation has been calculated as 10 min. The worker was rated at 80%. If the relaxation and other allowances were 50%, then the standard time could be _____ minutes.

Q.13 If the observed time for an operator is 18 min. and operator is rated as 130% and 10% allowances are given. The standard time for completing the job is _____.

Q.14 An industrial operation consists of four elements with following observed times and performance ratings

Elements	Observed time (min)	Performance rating (%)
1	0.15	80
2	0.20	85
3	0.10	90
4	0.12	75

Assuming rest and personal allowances are 12% and contingency allowance as 4% of the basic time. Then the standard time per piece _____ min.

Q.15 Work sampling study was conducted to determine the percentage of idle time of a automatic machine section. Assuming confidence level to be 95% and the error (accuracy required) to be ± 5%. Then the number of observations necessary to obtain the desired results will be _____.
[% of idle time = 0.25, for 95% confidence level, $z = 1.96$]

Q.16 An operations consultant for an automatic car wash wishes to plan for enough capacity to handle 60 cars per hour. Each car will have a wash time of 4 minutes but there is to be 30% allowance for set up time, delays and payment transactions. Car wash stalls should be installed equal to _____.

Q.17 In an industrial operation, following data are given

Representation time = 0.85 minute
Rating factor = 120%
Relaxation allowance = 11%
Personal allowance = 4% of Normal time
Delay allowance = 3%

Then, the standard time will be _____ min.

Q.18 A worker X, while working on a machine produced 75 numbers of the same job whose standard performance is 80 jobs per day. Labour hourly rate is ₹ 12. (Rate differential to be applied = 80% of standard piece rate for below standard performance). For 8 hours working period in a day the earning of the worker will be (₹/per day) _____.

Q.19 The molding process is used in preparing chocolate candy bar. Personal fatigue and delay allowances are set at 15%. The molding machine operator is rated at 120%. Observed times per batch are given below.

	Observed time in minutes			
Task	1	2	3	4
Molding	26	30	29	31

Then the standard time for the task is _____ min.

Q.20 A total of 15 observations has been taken on a head baker for a school district. The numerical breakdown of the baker's activities is

Make Ready	Do	Cleanup	Idle
2	6	3	4

(Assume 5 percent desired absolute accuracy and 95 percent confidence level)
Number of work-sampling observations are required to determine how much of the baker's time is spent in "doing" will be _____.

Answers

1. (c) 2. (c) 3. (d) 4. (c) 5. (c)
6. (b)

Hints and Explanations:

3. (d)
Work sampling is used for determining allowances in time study.

4. (c)

Transportation = $\Rightarrow$
Storage = ∇
Delay = D
Operation = O

7. 80(79 to 81)

Available working hour = 400 – 100 = 300
Actual worked hours = 240

$$\text{Percentage utilization} = \frac{240}{300}\times 100 = 80\%$$

8. 14.06 (13.75 to 14.25)

Standard time = 15 minutes
Rating factor (R.F.) = 0.8
Allowances = 25% = 0.25
Standard time = Normal time + Allowances
= Standard time = (Observed time) × R.F. + 0.25 × (Standard time)
15 = (Observed time) × 0.8 + 0.25 × 15
= 0.75 × 15 = Observed time × 0.8

$$\text{Observed time} = \left(\frac{0.75\times 15}{0.8}\right)$$

= 14.0625 $\simeq$ 14.06 minutes

9. (25)

$\eta_{Machine}$ = 80%
Scrap = 25%
Desired output = 1200 pieces per week
In a week = 40 hrs. available
In a year = 50 weeks available
$\therefore$ Useful component coming out of machine = 75%
Number of component required per year = 1200 × 50 = 60000/ years
Time available = 40 × 50
= 2000 hrs/ years
1 hr $\rightarrow$ 2 components
Actual component per machine/hr = 2 × 0.8 × 0.75 = 1.2
$\therefore$ 2000 × 1.2 × N = 60000
N = 25 machine

10. (2400)

p.s. = $k\sigma_p$

where $\sigma_p = \sqrt{\frac{p(1-p)}{n}}$

p = fraction occurrence of events
s = precision factor
k/s = confidence precision factor

Here, $p = \frac{40}{100} = 0.4$

$k = 2$ (95% confidence)

$s = 0.05$ (±2.5% accuracy)

$$p.s. = k\sqrt{\frac{p(1-p)}{n}}$$

$$\Rightarrow \quad p = \frac{k}{s}\sqrt{\frac{p(1-p)}{n}}$$

$$\Rightarrow \quad 0.4 = \frac{2}{0.05}\sqrt{\frac{0.4\times(1-0.4)}{n}}$$

$$\Rightarrow \quad n = 2400$$

11. (3.46)

Total number of observation,

$$N = 3000 + 2000 = 5000$$

Probability of idleness, $P = \frac{2000}{5000} = 0.4$

$$S \times P = k\sqrt{\frac{P(1-P)}{N}}$$

Where, P = idleness probability = 0.4

N = total number of observation = 5000

$k \approx 2$ for 95% confidence level of the work study

S = relative accuracy (we have to find)

$$S \times 0.4 = 2\sqrt{\frac{0.4\times0.6}{5000}}$$

$$S = \pm 0.03464 \text{ or } 3.46\%$$

Note: One of the basic assumptions concerning the accuracy of a work measurements system is that a find breakdown of motion variables contributes to the reduction of system deviation.

12. (12)

Observed time = 10 minutes

Normal time = 0.8 × 10 = 8 minutes

Standard time = 8 × 1.5 = 12 minutes

13. (25.74)

N.T. = O.T. × Rating

= 18 × 1.3 = 23.4 min.

Standard time = N.T. + 0.1 × N.T.

= 23.4 + 0.1 × 23.4 = 25.74 min.

(N.T. = Normal time)

(O.T. = Observed time)

14. (0.544)

Elements	Observed time (min)	Rating	Normal time (min)
1	0.15	80	$0.15 \times \frac{80}{100} = 0.12$
2	0.20	85	= 0.17
3	0.10	90	= 0.09
4	0.12	75	= 0.09
			= 0.47

Normal time per piece = 0.47 min.

Rest and personal allowance = $\frac{12}{100}\times 0.47$

= 0.056 min

Contingency allowance = $\frac{4}{100}\times 0.47$

= 0.0188 min.

Therefore, standard time = Normal time + allowances

= 0.47 + 0.056 + 0.018

= 0.544 min

15. (4610)

$$\text{P.L.} = Z_1\sqrt{\frac{P(1-P)}{n}}$$

$$0.25 \times 0.05 = 1.96\sqrt{\frac{0.25(1-0.25)}{n}}$$

$$L\begin{bmatrix} P = 0.25 \\ S = 0.05 \\ Z = 1.96 \end{bmatrix}$$

$$\left(\frac{0.25\times0.05}{1.96}\right)^2 = \frac{0.25\times0.75}{n}$$

$$n = 4609.92 \simeq 4610$$

16. (6)

Wash time for each car = 4 × 1.3 = 5.2 min

Number of cars washed in one hour in one stall

$$= \frac{60}{5.2} = 11.538$$

Number of car was stalls to be installed

$$= \frac{60}{11.538} = 5.2 \simeq 6$$

17. (1.204)

Total allowances = 4 + 3 + 11 = 18% of N.T. (NT = Normal Time)

Normal time = $0.85 \times 1.2 = 1.02$ minute

Standard time = Normal time + allowances

$= 1.02 + 0.18 \times 1.02$

= 1.2036 minutes

18. (72)

$$\text{Standard output per hour} = \frac{80}{8} = 10 \text{ jobs}$$

$$\text{Standard piece rate (R)} = \frac{12}{10} = ₹\ 1.2$$

Piece rate = $1.2 \times 0.8 = 0.96$

Earning of the worker = 0.96×75

= ₹ 72 per day

19. (40.02)

Average for the actual molding cycle

= 29 minutes per batch

Normal time = observed time × rating

$= 29 \times 1.2$

= 34.8 minutes per batch

Standard time = Normal time + Normal time × allowances

$= 34.8 + 34.8 \times 0.15$

= 40.02 minutes

20. (369)

$$N = \frac{z^2 P(1-P)}{e^2} \qquad \begin{pmatrix} z = 1.96 \\ e = 0.05 \end{pmatrix}$$

$$P = \text{“Doing”} = \frac{6}{15} = 0.4$$

$$N = \frac{(1.96)^2 (0.4)(1-0.4)}{(0.05)(0.05)}$$

$= 368.79 \simeq 369$

Student's Assignments

Q.1 Work sampling study is conducted in a machine shop and the date recorded are:
Total number of observation = 1000
Number of activity observation = 200
Ratio between manual to machine = 3 : 2 portion of activity
Rating factor = 120%
Total number of pieces produced = 240
Duration of study = 150 hours.
Calculate standard time per unit.

Ans. [40.32 min]

Q.2 Manufacturing of a component requires three operation to be performed in the different machines *A*, *B*, *C*. Observed time and the speed rating of the workers are given below:

M/C	Observed Time	Operation Rating
A	0.76 min	110%
B	1.28 min	94%
C	0.12 min	112%

If the factory operates for 2 shifts a day of 8 hours and for 6 days a week, find the number of machines required to produce 10000 components per week. Assume relaxation allowance time as 20%.

Q.3 The observed time in minutes for four cycles of an operation consisting of five elements using stop watch is as given below. Find the standard time per unit when element 2 and 4 are machine element and for rest operator is rated at 120%. Take total allowance as 20% of standard time.

Element	Cycle	Time	In	Min.
	1	2	3	4
1	4.8	4.9	4.9	4.8
2	6.15	6.05	6.10	6.10
3	2.90	3.00	2.95	2.95
4	7.20	7.25	7.30	7.25
5	3.45	3.35	3.40	3.40

Ans. [33.49 min]

■■■■