**Work Study**

Definition: Work study may be defined as the analysis of a job for the purpose of finding the preferred method of doing it and also determining the standard time to perform it by the preferred (or given) method. Work study, therefore, comprises two areas of study: method study (motion study) and time study (work measurement).

Role of Work Study in Improving Productivity

In order to understand the role of work study, we need to understand the role of method study and that of time study.

Method study (also sometimes called Work Method Design) is mostly used to improve the method of doing work. It is equally applicable to new jobs. When applied to existing jobs and existing jobs, method study aims to find better methods of doing the jobs that are economical and safe, require less human effort, and need shorter make-ready / put-away time. The better method involves the optimum use of best materials and appropriate manpower so that work is performed in a well organized manner leading to increased resource utilization, better quality and lower costs.

It can therefore be stated that through method study we have a systematic way of developing human resource effectiveness, providing high machine and equipment utilization, and making economical use of materials.

Time study, on the other hand, provides the standard time, that is the time needed by a worker to complete a job by the standard method. Standard times for different jobs are necessary for proper estimation of manpower, machinery and equipment requirements daily, weekly or monthly requirement of materials production cost per unit as an input to better make or buy decision labor budgets worker's efficiency and incentive wage payments.

By the application of method study and time study in any organization, we can thus achieve greater output at less cost and of better quality, and hence achieve higher productivity.

**Work Study and Ergonomics**

The work study and the ergonomics are the two areas of study having the same objective: design the work system so that for the operator it is safe, and the work is less fatiguing and less time taking.

Historical Developments

The Work of Taylor

Frederick W. Taylor is generally considered to be the founder of modern method and time study, although time studies were conducted in Europe many years before Taylor 's time. In 1760, Jean Rodolphe Perronet, a French engineer, made extensive time studies on the manufacture of No. 6 common pins.

Taylor began his time study work in 1881 while associated with the Midvale Steel Company in U.S.A.. He evolved a system based on the “task”, and proposed that the work of each employee be planned out by the management in advance. Each job was to have a standard time, determined by time studies made by experts. In the timing process, Taylor advocated dividing the work into small divisions of effort known as "elements." Experts were to time these individually and use their collective values to determine the allowed time for the task.

Early presentations of Taylor 's findings were received with little enthusiasm, because many interpreted his findings to be somewhat new piece-rate system rather than a technique for analyzing work and improving methods. Both management and employees were skeptical of piece rates, because many standards were earlier typically based on the supervisor's guess or even sometimes inflated by bosses to protect the performance of their departments. In June 1903, at the American Society of Mechanical Engineers meeting, Taylor presented his famous paper, "Shop Management," which included the elements of scientific management: time study, standardization of all tools and tasks, use of a planning department, use of slide rule and similar timesaving implements, instruction cards for workers, bonuses for successful performance, differential rates, mnemonic systems for classifying products, routing systems, and modern cost systems. Taylor 's techniques were well received by many factory managers, and by 1917, of 113 plants that had installed "scientific management," 59 considered their installations completely successful, 20 partly successful, and 34 failures.

In 1898, while at the Bethlehem Steel Company, Taylor carried out the pig-iron experiment that became the most celebrated demonstrations of his principles. He established the correct method, along with financial incentives, and workers carrying 92-pound pigs of iron up a ramp onto a freight car were able to increase their productivity from an average of 12.5 tons per day to between 47 and 48 tons per day. This work was performed with an increase in the daily rate of $1.15 to $1.85. Taylor claimed that workmen per-formed at the higher rate "without bringing on a strike among the men, without any quarrel with the men and were happier and better contented."

Another of Taylor 's Bethlehem Steel studies that became famous was on shoveling work. Workers who shoveled at Bethlehem would use the same shovel for any job—lifting heavy iron ore to lifting light rice coal. Taylor designed shovels to fit the different loads: short- handled shovels for iron ore, long-handled scoops for light rice coal, and showed their usefulness in improving productivity.

Not as well known as his engineering contributions is the fact that in 1881, he was a U.S. tennis doubles champion. Here he used an odd-looking racket he had designed with a spoon curved handle.

**The Work of Gilbreths**

Frank and Lilian Gilbreth are considered as the founders of the modern motion study technique, which may be defined as the study of the body motions used in performing an operation, for the purpose of improving the operation by eliminating unnecessary motions, simplifying necessary motions, and then establishing the most favorable motion sequence for maximum efficiency. Frank Gilbreth originally implemented ideas into the bricklayer's trade in which he was employed. After introducing methods improvements through motion study, including an adjustable scaffold that he had invented, as well as operator training, he was able to increase the average number of bricks laid from 120 to 350 per worker per hour.

More than anyone else, the Gilbreths were responsible for industry's recognition of the importance of a detailed study of body motions to arrive at the best method of performing an operation that would increase production, reduce operator fatigue. They developed the technique of filming motions for study, known as micro motion study.

The Gilbreths also developed the cyclegraphic and chronocyclegraphic analysis techniques for studying the motion paths made by an operator. The cycle- graphic method involves fixing a small electric light bulb to the finger or part of the body being studied and then photographing the motion while the operator is performing the operation. The resulting picture gives a permanent record of the motion pattern employed and can be analyzed for possible improvement. The chrono- cyclegraph is similar to the cyclegraph, but its electric circuit is interrupted regularly, causing the light to flash. Instead of showing solid lines of the motion patterns, the resulting photograph shows short dashes of light spaced in proportion to the speed of the body motion being photographed. Consequently, with the chronocyclegraph it is possible to determine direction and compute velocity, acceleration, and deceleration, in addition to study of body motions.

**The Work of Others**

Carl G. Barth, an associate of Frederick W. Taylor, developed a production slide rule for estimating the most efficient combinations of speeds and feeds for cutting metals of various hardnesses, considering the depth of cut, size of tool, and life of the tool. He is also known for his work on estimation of allowances by establishing the number of foot-pounds of work a worker could do in a day. He developed a relationship in which a certain push or pull on a worker's arms was equated with the amount or weight that worker could handle for a certain percentage of the day.

Harrington Emerson applied scientific methods to work on the Santa Fe Railroad and wrote a book, Twelve Principles of Efficiency, in which he made an attempt to lay down procedures for efficient operation. He reorganized the company, integrated its shop procedures, installed standard costs and a bonus plan, and introduced Hollerith tabulating machines for the accounting work. This effort resulted in an annual saving of $ 1.5 million and recognition of his approach, called efficiency engineering.

In 1917, Henry Laurence Gantt developed a simple graph that would present performance while visually showing projected schedules. This production control tool was adopted by the shipbuilding industry during World War I. For the first time, this tool demonstrated the possibility of comparing actual performance against the original plan, and to adjust daily schedules in accordance with capacity, backlog, and customer requirements. Gantt is also known for his wage payment system that rewarded workers for above-standard performance, eliminated any penalty for failure, and offered the boss a bonus for every worker who performed above standard. Gantt advocated human relations and promoted scientific management in the backdrop of an inhuman "speedup" of labor.

Motion and time study received an added stimulus during World War II when Franklin D. Roosevelt, through the U.S. Department of Labor, attempted to establish standards for increasing production. The stated policy advocated greater pay for greater output but without an increase in unit labor costs, incentive schemes to be collectively bargained between labor and management, and the use of time study for setting production standards.

**Method Study**

Method study, aims to achieve the better method of doing work, and for this reason method study is sometimes called Work Method Design.

Definition: Method study can be defined as the procedure for systematic recording, analysis and critical examination of existing or proposed methods of doing work for the purpose of development and application of easier and more effective methods.

Method Study Procedure

The following general steps describe the procedure for making a method study.

1. Select the job – on which method study is to be applied.
2. Obtain information and record.
3. Examine the information critically.
4. Develop the most practical, economical and effective method by considering real limitations of the situation.
5. Install the new method as standard practice.
6. Maintain the standard practice by regular follow up.

**Steps in some detail:**

Selection of Job for Method Study

Practically, any activity or a job is a potential project for improvement but as the work study engineer is to sell his ideas and maintain his existence in the organisation, he should always attempt to select those jobs for improvement which are unpopular among employees or are considered “dirty” by them.

By improving such jobs, he would earn goodwill from the employees as well as the management, and can expect their full cooperation for other studies in the future.

Considerations may be given to the following factors while selecting a job for method study

- Economic Factors
- Technical Factors
- Human Factors

Economic Factors:If the economic importance of a job is small, it is not wise to start or continue a long study. Priorities should be given to those types of job which offer greater potential for cost reduction. Such jobs are easily identifiable, as they have

- High labour content, i.e. they consume more time
- higher frequency of occurrence, i.e. they have large demand
- higher proportion of accidents
- high scrap and reprocessing costs
- excessive machine or man idleness
- bottlenecks in production line
- movement of material or men over long distance
- high payment of overtime bills.

Technical Factors: The method study engineer must have the necessary technical knowledge about the job to be studied. Only surface knowledge about the subject may not lead to the right solution to the real problem. To illustrate, consider that a particular machine tool in proving bottlenecks. The output from this machine is not reaching the assembly line in the required quantity. Through a preliminary study, it is found that it is running at lower speed and feed than that recommended for the pair of work and tool material used. Just an increase in speed or feed may not be the solution to this problem. It may be possible that the machine itself is not rigid enough to operate at higher speeds or take a deeper cut. Just an increase in speed may increase the output but the quality of job may be seriously affected. Technical expertise in machine tools and metal cutting processes would be essential to solve problems of this kind.

Human Factors: Emotional reaction of the workers to the method study and changes in method are important considerations. If the study of a particular job is suspected to cause unrest or ill feeling, it should not be undertaken, however useful it may be from the economic point of view. It is always better to take up first those jobs which are considered ‘dirty', unsafe, unpleasant, boring, or highly fatiguing, and improvements brought about as a result of method study. This would possibly ensure cooperative from the workers for the other jobs as well.

After it is recognized that a problem exists, the first step is to properly formulate it. From the general statements like “Costs are too high“, “Increase the production”, “Reduce shop floor accidents”, it is necessary to determine just what the real problem is. After it is ascertained that the problem merits consideration, it is decided whether this is the proper time to solve it, and how much time can be spent in solving it. The problem may then be defined broadly giving minimum constraints at this stage, as it will permit the use of imagination and creativity in finding a solution. It may sometimes be desirable to divide the complete problem into a couple of small problems and solve them.

**Information Collection and Recording**

Information Collection Techniques:

The accuracy of data about the method study problem is important for the development of improved method. The following techniques are used for the collection of information / data about the task under consideration. These are not exclusive of each other, and for any particular method study problem, some or all the techniques may be employed.

• Observation. It is a common technique used for collecting information about the present method or the existing problem. The method study person visits the site where the work is currently being done and observes various steps in the method being followed. There are many instances where all the data needed is obtained by only observing the work or work site.

• Discussion. Discussion with those who do or who supervise the work can frequently provide information not obtainable by observation. The discussion technique is commonly used where irregular work is involved or where one is trying to analyze past work in order to improve efficiency of work to be done in future.

Even where observation by itself may accomplish the data collection task, discussion may be used for developing good human relations.

• Records. Valuable information can be obtained from past records concerning production, cost, time, inventory and sub-contracts. For certain type of information concerning the past practice, sometimes this is the only way to obtain authentic data.

• Motion Pictures or video Films. Accurate and most detailed information can be obtained by taking motion pictures or video film. Information obtained by this procedure can easily be transmitted / forwarded to all levels in the organization and if needed, can be used directly for training purposes. The film can be used to focus attention at particular point or motion in an operation. For obtaining information concerning those types of work that involve large crew size, it is probably the only procedure.

Information Recording Techniques:

There are three main types of information recording techniques. These are

• Process Charts

• Diagrams

• Templates

A Process Chart is a graphic means of representing the activities that occur during a manufacturing or servicing job.

There are several types of process charts. These can be divided into two groups.

(i) Those which are used to record a process sequence (i.e. series of events in the order in which they occur) but do not depict the events to time scale.

Charts falling in this group are

• Operation process chart

• Flow process chart – (man / material / equipment type)

• Operator chart (also called Two Handed Process Chart)

(ii) Those which record events in the sequence in which they occur on a time scale so that the interaction of related events can be more easily studied. Charts falling in this group are

• Multiple activity chart

• Simo chart

**Diagrams-** A diagram gives pictorial view of the layout of workplace or floor on which locations of different equipment, machines, etc. are indicated. The movement of subject (man or material) is then indicated on the diagram by a line or a string. The diagrams are valuable in highlighting the movement so that analyst can take steps to simplify or reduce it and thus effect saving in time or reduction in collisions / accidents.

Two types of diagrams are common: Flow diagram and string diagram.

Templates and 3-D models:

Two-dimensional cut outs made from thin card sheet representing machinery, furniture, etc. can be used for developing new layouts and methods. The templates may have pieces of permanent magnet attached to them, so that when used on iron board; they remain glued on the board whenever placed.

A scaled 3-D model of a working area helps easy understanding of lighting, ventilation, maintenance and safety aspects that may be important in a method. Such models are often of great value in demonstrating the advantages of the proposed changes to all concerned. However, their use is limited because of higher cost involved. Some computer softwares are available which help in constructing the layout and possibility of visualizing the working of process in a systematic way.

Before taking up descriptions of these charts or diagrams, it is necessary to know the various elements of work.

Elements of Work:

There are five basic elements of work: Operation, Inspection, Transportation, Delay, and storage. Table gives the definitions and symbols by which these elements are represented. Also given in the Table are examples of each element.

Sometimes, more than one element occur simultaneously. It is shown as combined element with combined symbol. Examples are "Operation in combination will inspection", and "Inspection in combination with Transportation".

Operation Process Chart:

An operation process chart provides the chronological sequence of all operations and inspections that occur in a manufacturing or business process. It also shows materials used and the time taken by operator for different elements of work. Generally a process chart is made for full assembly, that is, it shows all the operations and inspections that occur from the arrival of raw material to the packaging of the finished product.

Flow Process Chart:

A flow process chart is used for recording greater detail than is possible in an operation process chart. It is made for each component of an assembly rather than for the whole assembly.

A flow process chart shows a complete process in terms of all the elements of work. There are two main types of flow charts: product or material type , and the operator type . The product type records the details of the events that occur to a product or material, while the operator flow chart details how a person performs an operational sequence.

An important and valuable feature of this chart is its recording of non-productive hidden costs, such as delays, temporary storages, unnecessary inspections, and unnecessary long distances traveled. When the time spent on these non productive activities is highlighted, analyst can take steps to minimize it and thus reduce costs.

Operator Process Chart :

It is also called Left Hand – Right Hand chart and shows the activities of hands of the operator while performing a task. It uses four elements of hand work: Operation, Delay (Wait), Move and Hold. Its main advantage lies in highlighting un-productive elements such as unnecessary delay and hold so that analyst can take measures to eliminate or shorten them.

Multiple Activity Chart:

Worker-Machine process chart and gang process chart fall in the category of multiple activity charts. A worker-machine chart is used for recording and analyzing the working relationship between operator and machine on which he works. It is drawn to time scale. Analysis of the chart can help in better utilization of both worker and machine time. The possibility of one worker attending more than one machine is also sought from the use of this chart.

A gang process chart is similar to worker-machine chart, and is used when several workers operate one machine. The chart helps in exploring the possibility of reducing both the operator time and idle machine time.

Simo Chart:

A Simo chart is another Left-Hand Right-Hand chart with the difference that it is drawn to time scale and in terms of basic motions called therbligs. It is used when the work cycle is highly repetitive and of very short duration.
CRITICAL EXAMINATION

Critical examination of the information recorded about the process in charts / diagrams is the most important phase of the method study. In this, each element of the work, as presently being done and recorded on the chart is subjected to a systematic and progressive series of questions with the purpose of determining true reasons for which it is done. Based on the reasons, improvements are found and adopted into a new method, called better method. This examination, thus requires exhaustive collaboration with everyone whose contribution can prove useful, and also full use of all available sources of technical information. The use of questioning technique reduces the possibility of missing any information which may be useful for the development of better method.

A popular procedure of carrying out critical examination uses two sets of questions: Primary questions (answers to these show up the necessity of carrying out the activity), and Secondary questions (answers to these allow considerations to alternative methods of doing the activity). Selection of the best way of doing each activity is later determined to develop new method which is introduced as a standard practice.

A general-purpose set of primary and secondary questions is given below:

Primary Questions:
1. Purpose. The need of carrying out the activity is challenged by the questions-What is achieved? Is it necessary? Why?
The answers to these questions determine whether the particular activity will be included in the proposals of new method for the process.
2. Means. The means of carrying out the activity are challenged by the questions- 'How is it done?' and 'Why that way'?
3. Place. The location of carrying out the activity is challenged by the questions- 'Where is it done'? and 'Why there'?
4. Sequence. The time of carrying out the activity is challenged by the questions- 'When is it done'? and 'Why then'?
5. Person. The level of skill and experience of the person performing the activity is challenged by the questions- 'Who does it'? and 'Why that person'?

The main object of the primary questions is to make sure that the reasons for every aspect of the presently used method are clearly understood. The answers to these questions should clearly bring out any part of the work which is unnecessary or inefficient in respect of means, sequence, person or place.

Secondary Questions:
The aim of secondary questions is to arrive at suitable alternatives to the presently used method:

1. Purpose. If the answer to the primary question 'Is the activity necessary''? is convincingly 'Yes', alternatives to achieve the object of carrying nut the activity are considered by the question— 'What else could be done'?

2. Means. All the alternative means to achieve the object are considered by the question— 'How else could it be done'?

3. Place. Other places for carry ing out the activity are considered by the question— 'Where else could it be done'?

4. Sequence. The secondary question asked under this heading is— 'When else could it be clone'?

5. Person. The possibilities for carrying out the activity by other persons are considered by asking the question- 'Who else should do it' ?

This phase involves the search of alternative possibilities within the imposed restrictions of cost, volume of production, and the like. For this the method study man uses his own past experience with same or similar problems or refers to text books, handbooks, etc.
The answers to the following questions are then sought through evaluation of the alternatives.

'What should be done'? 'How should it be done'? 'Where should it be done'? 'When should it be done'? & 'Who should do it'?

These answers form the basis of the proposals for the improved method. The evaluation phase requires the work study man to consider all the possibilities with respect to the four factors—economic, safety, work quality and human factors—the economic factor being the most important in most situations.

Economic considerations to any alternative refer to determination of 'How much will it cost'? and 'How much will it save'? The purpose of evaluating safety factor is to ensure that the alternative selected shall not make the work less safe. The evaluation of quality factor shall determine whether the alternative selected shall make for better product quality or quality control.

And lastly human factors considerations shall ensure that the new method will be interesting, easy to learn, safe, less monotonous and less fatiguing to the operator.

Developing Better Method:

With the present method or procedure for the job in mind, the application of ‘critical analysis' highlights the essential part of the job, for which alternative ways for its carrying out are developed .

When developing alternative ways for doing a task the following may be considered.

- Where and how to use ‘man' in the process?

• What better work procedure be adopted?

• What better equipment be used?

• What better layout of work station, shop or factory be used?

In deciding whether a particular element of work (operation, inspection, or transportation) be carried out manually or with the help of a device, method study engineer must be well aware of things which man cannot do or does in inferior fashion than machine. Examples of such things are:

Exert large amount of force, as needed in metal cutting.
Exert force precisely or smoothly at a fixed rate as needed in metal forming.
Do high speed computations of complex nature.
Perform repetitive tasks without suffering from side effects like boredom, fatigue, etc.
Move at high speeds for hours together.
Carry out several tasks simultaneously.
Respond fast to frequently changing control signals.
Perform satisfactorily in an environment where conditions relating to cold, heat, noise, dampness, etc. are extreme.
In contrast, machines prove inferior generally when for carrying out a task it is necessary to

Think creatively or inductively
Learn
Generalize
Cope will unexpected events.
In most cases, the relative roles of man and machine vary from one extreme end in which entire process is manual to the other extreme in which the process is completely mechanized with the presence of man only for monitoring, trouble shooting, maintenance, and the like.

Man is readily available and extremely flexible tool, who has the capability of doing a large number and type of tasks with learning and practice that is generally less expensive than the cost of creating devices for the same purpose. Man is therefore considered a strong competitor for low, medium and even some high volume production tasks.

When an activity is decided to be carried out manually, the best work procedure is determined by considering the principles of Motion Economy.

Equipped will the various alternative ways of carrying out essential elements of task, method study engineer has now to choose the best alternative method. He decides upon the criteria, which may be additional fixed costs involved, running cost, production rate, operator's fatigue, operator learning time, and the like. The weight to each criterion is fixed and performance is predicted of each alternative with respect to each criteria. The one which gets the maximum points is selected for adoption as a standard method.

Detailed specifications of this method are prepared with the description of procedure, workplace layout and material/equipment to be used. This is important for

• Communication of the proposed work method to those responsible for its approval

• Communication of the proposed method to those concerned with its installation, for example instructors and supervisors who are actually responsible for instructions to operators and setting up the machinery and work place layouts.

• Official record of the work method.

Installation of Improved Method:

When the proposals of the improved method for a job are approved by the management of the company, the next step is to put this method into practice. Installation of method requires necessary prior preparation for which the active support of everyone concerned is very important.

The activities of the installation phase include:

1. Gaining acceptance of the change by the workers involved and their representatives. The method change may affect the routine and paper work of wages, costs, planning, and even purchase department. It may require displacement of staff from one section to another of the organisation. Adjustments of this type need to be carried out very carefully so that the least possible hardship or inconvenience is caused.

2. Retraining the workers. The extent to which workers need retraining will depend on the nature of the job and the changes involved. It is much more for those jobs which have a high degree of manual dexterity and where the workers have been doing the work by traditional methods. The use of films demonstrating the advantages of new method as compared to traditional one are often very useful in retraining the workers.

3. Arranging the requirements of the new method. This involves -

(i) arranging the necessary plant, tools and equipment at all the workplaces,

(ii) arranging building-up of necessary stocks of new raw materials, and running-down of old stocks,

(iii) checking up the availability and continuity of all supplies and services, and

(iv) arranging any clerical records which may be required for purposes of control and comparison.

4. Taking other necessary actions. These will depend upon situation to situation. For example, if changes in working hours are involved, necessary instructions should be passed on to auxiliary services such as transport, canteen, water supply, etc. If change in wages is involved, information concerning the date of installation must reach the costing department. Necessary instructions should be passed on to everyone concerned about the time table for the installation of the change in method.

5. Giving a trial run to the new method. It is important that all departments affected by the change are represented at the rehearsal. It is often advantageous to conduct the rehearsal while the old method is still operating. It should usually take place outside normal working hours; say at week-end or at holiday time so that there is no interference with normal production. The suggestions for minor variations in the proposed method if they are worthwhile and cost effective should be accepted and incorporated.

It is obvious that the method analyst has to be extra tactful and keep restraint throughout the period of installation. The installation is considered complete when the new method starts running smoothly.

Follow-up:

The work of method study man is not complete with the installation of the improved method; the maintenance of the new method in its specified form is also part of his activities. The main aim of maintenance of the new method is to ensure that the workers do not slip back into the old method, or introduce elements which are not part of the proposed method.

For effective maintenance it is important to define and specify the new method very clearly. An operator chart giving adequate details of the tools, equipment, and workplace layout and operator-motion pattern is often helpful.

The workers have a tendency to drift away from the method laid down. The purpose of the method-maintenance is to check this tendency. But if it is found that the change from the method specified is in fact an improvement which can be made in the method, this should be officially incorporated.

**Motion Study**

Motion study is a technique of analyzing the body motions employed in doing a task in order to eliminate or reduce ineffective movements and facilitate effective movements. By using motion study and the principles of motion economy the task is redesigned to be more effective and less time consuming.

The Gilbreths pioneered the study of manual motions and developed basic laws of motion economy that are still relevant today. They were also responsible for the development of detailed motion picture studies, termed as Micro Motion Studies, which are extremely useful for analyzing highly repetitive manual operations. With the improvement in technology, of course, video camera has replaced the traditional motion picture film camera.

In a broad sense, motion study encompasses micro motion study and both have the same objective: job simplification so that it is less fatiguing and less time consuming. While motion study involves a simple visual analysis, micro motion study uses more expensive equipment. The two types of studies may be compared to viewing a task under a magnifying glass versus viewing the same under a microscope. The added detail revealed by the microscope may be needed in exceptional cases when even a minute improvement in motions matters, i.e. on extremely short repetitive tasks.

Taking the cine films @ 16 to 20 frames per second with motion picture camera, developing the film and analyzing the film for micro motion study had always been considered a costly affair. To save on the cost of developing the film and the cost of film itself, a technique was used in which camera took only 5 to 10 frames per minute. This saved on the time of film analysis too. In applications where infrequent shots of camera could provide almost same information, the technique proved fruitful and acquired the name Memo Motion Study.

Traditionally, the data from micro motion studies are recorded on a Simultaneous Motion (simo) Chart while that from motion studies are recorded on a Right Hand - Left Hand Process Chart.

**Therbligs**

On analysing the result of several motion studies conducted, Gilbreths concluded that any work can be done by using a combination of some or all of 17 basic motions, called Therbligs (Gilbreth spelled backward). These can be classified as effective therbligs and ineffective therbligs. Effective therbligs take the work progress towards completion. Attempts can be made to shorten them but they cannot be eliminated. Ineffective therbligs do not advance the progress of work and therefore attempts should be made to eliminate them by applying the Principles of Motion Economy. Table gives different therbligs along with their symbols and descriptions.

SIMO Chart

It is a graphic representation of an activity and shows the sequence of the therbligs or group of therbligs performed by body members of operator. It is drawn on a common time scale. In other words, it is a two-hand process chart drawn in terms of therbligs and with a time scale, see Figure.

Making the Simo Chart. A video film or a motion picture film is shot of the operation as it is carried out by the operator. The film is analyzed frame by frame. For the left hand, the sequence of therbligs (or group of therbligs) with their time values are recorded on the column corresponding to the left hand. The symbols are added against the length of column representing the duration of the group of therbligs. The procedure is repeated for the right hand and other body members (if any) involved in carrying out the operation.
It is generally not possible to time individual therbligs. A certain number of therbligs may be grouped into an element large enough to be measured as can be seen in Figure.

Uses of SIMO Chart

From the analysis shown about the motions of the two hands (or other body members) involved in doing an operation, inefficient motion pattern can be identified and any violation of the principle of motion economy can be easily noticed. The chart, therefore, helps in improving the method of doing an operation so that balanced two-handed actions with coordinated foot and eye motions can be achieved and ineffective motions can be either reduced or eliminated. The result is a smoother, more rhythmic work cycle that keeps both delays and operator fatigue to the minimum extent.

**Cycle graph and Chrono cycle graph**

These are the techniques of analyzing the paths of motion made by an operator and were originally developed by the Gilbreths. To make a cycle graph , a small electric bulb is attached to the finger, hand, or any other part of the body whose motion is to be recorded. By using still photography, the path of light of bulb (in other words, that of the body member) as it moves through space for one complete cycle is photographed. The working area is kept relatively less illuminated while photograph is being taken. More than one camera may be used in different planes to get more details. After the film is developed, the resulting picture (cycle graph) shows a permanent record of the motion pattern employed in the form of a closed loop of white continuous line with the working area in the background. A cycle graph does not indicate the direction or speed of motion.

It can be used for

Improving the motion pattern, and
Training purposes in that two cycle graphs may be shown with one indicating a better motion pattern than the other.
The chrono cycle graph is similar to the cycle graph, but the power supply to the bulb is interrupted regularly by using an electric circuit. The bulb is thus made to flash. The procedure for taking photograph remains the same. The resulting picture (chrono cycle graph), instead of showing continuous line of motion pattern, shows short dashes of line spaced in proportion to the speed of the body member photographed. Wide spacing would represent fast moves while close spacing would represent slow moves. The jumbling of dots at one point would indicate fumbling or hesitation of the body member. A chrono cycle graph can thus be used to study the motion pattern as well as to compute velocity, acceleration and retardation experienced by the body member at different locations. Figures show a cycle graph and a chrono cycle graph.

The world of sports has extensively used this analysis tool, updated to video, for the purpose of training in the development of form and skill.

Principles of Motion Economy:

These principles can be considered under three different groups.

- Those related to the use of the human body.
- Those related to the workplace arrangement, and
- Those related to the design of tools and equipment.

1. Principles related to the use of human body:

(i) Both hands should begin and end their basic divisions of activity simultaneously and should not be idle at the same instant, except during the rest periods.

(ii) The hand motions should be made symmetrically and simultaneously away from and toward the centre of the body.

- Momentum should be employed to assist the worker wherever possible, and it should be reduced to a minimum if it must be overcome by muscular effort.
- Continuous curved motions should be preferred to straight line motions involving sudden and sharp changes in the direction.
- The least number of basic divisions should be employed and these should be confined to the lowest practicable classifications. These classifications, summarized in ascending order of time and fatigue expended in their performance, are:
- Finger motions
- Finger and wrist motions.
- Finger, wrist, and lower arm motions.
- Finger, wrist, lower arm, and upper arm motions.
- Finger, wrist, lower arm, upper arm motions and body motions.
- Work that can be done by the feet should be arranged so that it is done together with work being done by the hands. It should be recognized, however, that it is difficult to move the hand and foot simultaneously.
- The middle finger and the thumb should be used for handling heavy loads over extended periods as these are the strongest working fingers. The index finger, fourth finger, and little finger are capable of handling only light loads for short durations.
- The feet should not be employed for operating pedals when the operator is in standing position.
- Twisting motions should be performed with the elbows bent.
- To grip tools, the segment of the fingers closed to the palm of the hand should be used.

2. Principles related to the arrangement and conditions of workplace:

- Fixed locations should be provided for all tools and materials so as to permit the best sequence and eliminate search and select .
- Gravity bins and drop delivery should be used to reduce reach and move times. Use may be made of ejectors for removing finished parts.
- All materials and tools should be located within the normal working area in both the vertical and horizontal plane ( see Figure ), and as close to the point of use as possible.
- Work table height should permit work by the operator in alternately sitting and standing posture.
- Glare-free adequate illumination, proper ventilation and proper temperature should be provided.
- Dials and other indicators should be patterned such that maximum information can be obtained in minimum of time and error.

3. Principles related to the design of tools and equipment:

- Use colour, shape or size coding to maximize speed and minimize error in finding controls.

• Use simple on/off, either/or indicators whenever possible. If simple on/off indicator is not sufficient, use qualitative type indicator, and use quantitative type indicator only when absolutely essential.

• All levers, handles, wheels and other control devices should be readily accessible to the operator and should be designed so as to give the best possible mechanical advantage and utilize the strongest available muscle group. Their direction of motion should conform to stereo-typed reactions.

• Use quick acting fixture to hold the part or material upon which the work is being performed.

• Use stop guides to reduce the control necessary in positioning motions.

• Operating, set-up and emergency controls should be grouped according to the function.

Design of Workplace Layout

The design of workplace layout involves the following

Determination of work surface height
Design of operator chair (if work is to be done in sitting posture), or allowing the use of antifatigue mats for standing operator
Determination of location of tools, materials, controls, displays and other devices.
We shall consider these briefly.

Work Place Height

This should be decided from the standpoint of comfortable working posture for the operator. Generally, it is equal to the elbow height of operator whether work is done in standing or sitting posture. However, for work involving lifting of heavy parts, it is useful to lower the work surface height by as much as 20 cm. This would reduce the fatigue to the trunk of operator. Similarly, it may be useful to raise the work surface height when work involves visual examination of minute details of fine parts. This would reduce the eye fatigue to the operator. Alternatively, the work surface may be inclined by 15 degrees or so. Work surface height may also be made adjustable in situations where operator is permitted to do work in alternatively sitting and standing postures.

Design of Operator Chair

A seated posture is better than standing posture from the standpoint of stress reduction on the feet and the overall energy expenditure. A well-designed seat should

Provide trunk stabilization so that a good posture is maintained,
Permit change of posture, and
Not unduly press the thigh tissues.
This requires the use of ergonomic considerations and anthropometric dimensions of operator so that appropriate dimensions are chosen for the following features of chair

(i) Seat Height

(ii) Seat Depth

(iii) Seat Width

(iv) Seat Inclination

(v) Arm Rests

(vi) Back Rest

(vii) Foot Rest

It is necessary to provide adjustability, particularly with respect to seat height, in order that the same seat (or chair) is useable by many operators doing same job.

Standing for long periods of time on a cemented floor is fatiguing. If operator has to work only in standing posture, it is essential to provide resilient anti-fatigue floor mats. Such mats allow small muscle contractions in the legs and force the blood to keep circulating.

Determination of location of tools, materials, controls, displays and other devices.

We all know that greater the distance through which operator moves his body member while doing work, larger is the requirement of muscular effort, control and time. This means that all tools, materials, controls, etc need to be located within close reach of the operator. In this context, two areas can be identified: normal working area and maximum working area. Figure identifies these areas in horizontal and vertical planes.

Within these areas, all tools, materials, controls, displays and other devices must be located on the basis of any of the following principles.

(i) Importance Principle. According to this principle, the most important item or group of items is first located within the normal area in the best position. The next important component item or group of items is then selected and located in the best location within the remaining area. In this way, all the items are located.

(ii) Frequency of Use Principle. According to this principle, the item with the greatest frequency of use has the highest priority for location at the optimum position. From within the remaining items to be located in the remaining area, the same principle can then be applied repetitively.

(iii) Functional Principle. This principle provides for grouping of items according to their function. For instance, all controls that are functionally related may be grouped together and located at one place.

(iv) Sequence of Use Principle. According to this principle, items are located according to sequence of their use. For illustration, let us consider the case of assembly. As we know, an assembly is made by assembling the sub-assemblies in a specific order. From motion economy or production efficiency point of view, it would be better if sub-assemblies and other items are located in the sequence in which they are to be used in assembly.

Further, for better productivity, it is important that location of all tools, materials and controls be fixed so that their "search" and “select" is minimized.

**Work Measurement**

Work measurement refers to the estimation of standard time for an activity, that is the time allowed for completing one piece of job by using the prescribed method. Standard time can be defined as the time taken by an average experienced worker for the job with provisions for delays beyond the worker's control.

There are several techniques used for estimation of standard time in industry. These include time study, work sampling, standard data, and predetermined motion time system.

Applications:

Standard times for operations are useful for several applications in industry, like

• Estimating material, machinery, and equipment requirements.

• Estimating production cost per unit as an input to
Preparation of budgets
Determination of selling price
Make or buy decision
• Estimating manpower requirements.

• Estimating delivery schedules and planning the work

• Balancing the work of operators working in a group.

• Estimating performance of workers and using that as the basis for incentive payment to those direct and indirector labor who show greater productivity.

We will study some of the popular techniques of work measurement.

**TIME STUDY**
It is the most versatile and the most widely used technique of work measurement.

Definition:

Time study is a technique to estimate the time to be allowed to a qualified and well-trained worker working at a normal pace to complete a specified task by using specified method.

This technique is based on measuring the work content of the task when performed by the prescribed method, with the allowance for fatigue and for personal and unavoidable delays.

Time Study Procedure:

The procedure for time study can best be described step-wise, which are self explanatory.

Step 1: Define objective of the study. This involves statement of the use of the result, the precision desired, and the required level of confidence in the estimated time standards.

Step 2: Verify that the standard method and conditions exist for the operation and the operator is properly trained. If need is felt for method study or further training of operator, the same may be completed before starting the time study.

Step 3: Select operator to be studied if there are more than one operator doing the same task.

Step 4: Record information about the standard method, operation, operator, product, equipment, and conditions on the Time Study observation sheet.

Step 5: Divide the operation into reasonably small elements, and record them on the Time Study observation sheet.

Step 6: Time the operator for each of the elements. Record the data for a few number of cycles on the Time Study observation sheet. Use the data to estimate the total number of observations to be taken.

Step 7: Collect and record the data of required number of cycles by timing and rating the operator.

Step 8: Calculate the representative watch time for each element of operation. Multiply it by the rating factor to get normal time.

Normal time = Observed time x Rating factor

Calculate the normal time for the whole operation by adding the normal time of its various elements.

Step 9: Determine allowances for fatigue and various delays.

Step 10: Determine standard time of operation.

Standard time = Normal time + allowances

Selection of job for Time Study

Time Study is conducted on a job

- which has not been previously time-studied.
- for which method change has taken place recently.
- for which worker(s) might have complained as having tight time standards.

Selection of Worker for Time Study
The selection of worker for time study is a very important factor in the success of the study. If there is only one person on the job, as usually is, then there is no choice. But if more than one person is performing the same operation, the time study man may time one or more of the workers. If all the workers are using the same method for doing the job and there is different in the rate of their doing it, it is necessary to select a suitable worker for the study. The worker on which time study should be conducted must have necessary skill for the job, have sufficient experience with the given method on the job (that is, he should have crossed the learning stage), be an ‘average' worker as regards the speed of working, be temperamentally suited to the study (those who can't work in normal fashion when watched, are not suitable for the study), have knowledge about the purpose of study.

Time Study Equipment
The following equipment is needed for time study work.

- Timing device
- Time study observation sheet
- Time study observation board
- Other equipment

Timing Device. The stop watch ( see Figure ) is the most widely used timing device used for time study, although electronic timer is also sometimes used. The two perform the same function with the difference that electronic timer can measure time to the second or third decimal of a second and can keep a large volume of time data in memory.

Time Study Observation Sheet. It is a printed form with spaces provided for noting down the necessary information about the operation being studied, like name of operation, drawing number, and name of the worker, name of time study person, and the date and place of study. Spaces are provided in the form for writing detailed description of the process (element-wise), recorded time or stop-watch readings for each element of the process, performance rating(s) of operator, and computation. Figure shows a typical time study observation sheet.

Time Study Board. It is a light -weight board used for holding the observation sheet and stopwatch in position. It is of size slightly larger than that of observation sheet used. Generally, the watch is mounted at the center of the top edge or as shown in Figure near the upper right-hand corner of the board. The board has a clamp to hold the observation sheet. During the time study, the board is held against the body and the upper left arm by the time study person in such a way that the watch could be operated by the thumb/index finger of the left hand. Watch readings are recorded on the observation sheet by the right hand.

Other Equipment. This includes pencil, eraser, device like tachometer for checking the speed, etc.

Dividing Work into Short Elements

Timing a complete task as one element is generally not satisfactory. For the purpose of time study the task is normally broken into short elements and each element is timed separately, for the following reasons:

(1) To separate unproductive part of task from the productive one.

(2) To improve accuracy in rating. The worker may not work at the same speed throughout the cycle. He may perform some elements faster and some slower. Breaking of task into short elements permits rating of each element separately which is more realistic than just rating once for the complete cycle.

(3) To identify elements causing high fatigue. Breaking of task into short elements permits giving appropriate rest allowances to different elements.

(4) To have detailed job specifications. This helps in detection of any variation in the method that may occur after the time standard is established.

(5) To prepare standard data for repeatedly occurring elements.

The following guidelines should be kept in mind while dividing a task into elements.

(1) The elements should be of as short duration as can be accurately timed. (This in turn, depends on the skill of the time study man, method of timing and recording, and many other factors. Generally, with the stop watch, elements of duration less than 0.03 to 0.05 minute are difficult to time accurately. The elements should not normally be longer than 0.40 min.).

(2) Manually performed elements should be separated from machine paced elements. (Time for machine paced elements can be determined by calculation). Machine elements are not rated against a normal. This rule also helps in recognition of delays.

(3) Constant elements should be separated from variable elements. (Constant elements are those elements which are independent of the size, weight, length, or shape of the workpiece. For example, the time to pick screw driver from its place and bring it to the head of a screw is constant, whereas the time to tighten or loosen the screw is a variable, depending upon the length and size of the screw).

(4) The beginnings and endings of elements should be easily distinguishable. These should preferably be associated with some kind of sound.

(5) Irregular elements, those not repeated in every cycle, should be separated from regular elements. For example, if the jig is cleaned off after every ten parts produced, "cleaning" is an irregular element, and its time should be spread over ten cycles.
(6) Unnecessary motions and activities should be separated from those considered essential.

(7) Foreign or accidental elements should be listed separately. Such elements are generally of non-repetitive type.

Number of cycles to be timed.

The following general principles govern the number of cycles to get the representative average cycle time.

(1) Greater the accuracy desired in the results, larger should be the number of cycles observed.

(2) The study should be continued through sufficient number of cycles so that occasional elements such as setting-up machine, cleaning of machine or sharpening of tool are observed for a good number of times.

(3) Where more than one operator is doing the same job, short study (say 10 to 15 cycles) should be conducted on each of the several operators than one long study on a single operator.

It is important that enough cycles are timed so that reliable average is obtained.

Following techniques are used to determine the number of cycles to be timed.

(i) Use of Tables: On the consideration of the cost of obtaining the data and the desired accuracy in results, most companies have prepared their own tables for the use of time study people, which indicate the number of cycles to be timed as a function of the cycle time and the frequency of occurrence of the job in the company. For example, one Company uses the Table for such purposes.

(ii) Statistical methods: On the basis of the requirements of the particular situation involved, accuracy and confidence level are decided (An accuracy of a confidence level of 95% is considered reasonable in most cases). A preliminary study is conducted in which some (say N) cycles are timed. Standard deviation o of these (N) observations is calculated as

(iii) Mundel Method: In this method the following steps are followed.

Step 1. Take a few good watch readings of the work cycle. (Generally, 10 readings are taken if cycle time is less than 2 minutes, otherwise 5 readings).

Step 2. Find the ratio , where H and L are respectively the highest and the lowest value of the leading.

Step 3. Corresponding to the value of the ratio, determine the number of observations from the Table.

Normal Performance

There is no universal concept of Normal Performance. However, it is generally defined as the working rate of an average qualified worker working under capable supervision but not under any incentive wage payment scheme. This rate of working is characterized by the fairly steady exertion of reasonable effort, and can be maintained day after day without undue physical or mental fatigue.

The level of normal performance differs considerably from one company to another. What company a calls 100 percent performance, company B may call 80 percent, and company C may call 125 percent and so on. It is important to understand that the level that a company selects for normal performance is not critical but maintaining that level uniform among time study persons and constant with the passage of time within the company is extremely important.

There are, of course, some universally accepted benchmark examples of normal performance, like dealing 52 cards in four piles in 0.5 minute, and walking at 3 miles per hour (4.83 km/hr). In order to make use of these benchmarks, it is important that a complete description about these be fully understood, like in the case of card dealing, what is the distance of each pile with respect to the dealer, technique of grasping, moving and disposal of the cards.

Some companies make use of video films or motion pictures for establishing what they consider as normal speed or normal rate of movement of body members. Such films are made of typical factory jobs with the operator working at the desired normal pace. These films are found to be useful in demonstrating the level of performance expected from the operators and also for training of time study staff.

**Performance Rating**

During the time study, time study engineer carefully observes the performance of the operator. This performance seldom conforms to the exact definition of normal or standard. Therefore, it becomes necessary to apply some 'adjustment' to the mean observed time to arrive at the time that the normal operator would have taken to do that job when working at an average pace. This 'adjustment' is called Performance Rating.

Determination of performance rating is an important step in the work measurement procedure. It is based entirely on the experience, training, and judgment of the work-study engineer. It is the step most subjective and therefore is subject to criticism.

Performance Rating can be defined as the procedure in which the time study engineer compares the performance of operator(s) under observation to the Normal Performance and determines a factor called Rating Factor.

$$\text{Rating Factor} = \frac{\text{Observed Performance}}{\text{Normal Performance}}$$

**System of Rating**

There are several systems of rating the performance of operator on a job.

These are:

- Pace Rating
- Westinghouse System of Rating
- Objective Rating
- Synthetic Rating

A brief description of each rating method follows.

**Pace Rating**

Under this system, operator's performance is evaluated by considering his rate of accomplishment of the work. The study person measures the effectiveness of the operator against the concept of normal performance and then assigns a percentage to indicate the ratio of the observed performance to normal or standard performance.

In this method, which is also called the speed rating method, the time study person judges the operators speed of movements, i.e. the rate at which he is applying himself, or in other words "how fast" the operator performs the motions involved.

**Westinghouse System of Rating**

This method considers four factors in evaluating the performance of operator: skill, effort, conditions, and consistency.

Skill may be defined as the proficiency at of an individual in following the given method. It is demonstrated by co-ordination of mind and hands. A person's skill in a given operation increases with his experience on the job, because increased familiarity with work brings speed, smoothness of motions and freedom from hesitations.

The Westinghouse system lists six classes of each factor. For instance the classes of skill are poor, fair, average, good, excellent and superskill, as given in a Table . Each class has further two degrees. The time study person evaluates the skill displayed by the operator. And puts it in one of the six classes and also decides the degree in that class, higher or lower, i.e. 1 or 2. As equivalent % value of each class of skill is provided in the Table, the rating is translated into its equivalent percentage value, which ranges from +15 % (for super skill of higher degree) to -22 % (for poor skill of lower degree).

In a similar fashion, the ratings for effort, conditions, and consistency are given using the Table for each of the factors. By algebraically combining the ratings with respect to each of the four factors, the final performance-rating factor is estimated.

**Objective Rating**

In this system, speed of movements and job difficulty are rated separately and the two estimates are combined into a single value. Rating of speed or pace is done as discussed earlier, and the rating of job difficulty is done by selecting adjustment factors corresponding to characteristics of operation with respect to (i) amount of body used, (ii) foot pedals, (iii) bimanual ness, (iv) eye-hand co-ordination, (v) handling requirements and (vi) weight handled or resistance encountered. Mundel and Danner have given Table of % values (adjustment factors) for the effects of various difficulties in the operation performed.

For an operation under study, a numerical value for each of the six factors is assigned, and the algebraic sum of the numerical values called job difficulty adjustment factor is estimated.

The rating factor R can be expressed as

R = P x D

Where: P = Pace rating factor, and

D = Job difficulty adjustment factor.

**Synthetic Rating**

This method of rating has two main advantages over other methods. These are (i) it does not rely on the judgment of time study person and (ii) it gives consistent results.

The time study is made as usual. Some manually controlled elements of the work cycle are selected. Using a PMT system (Pre-determined motion time system), the times for these selected elements are determined. The times of these elements as determined are compared with the actual observed times and the performance factor is estimated for each of the selected elements.

Performance or Rating Factor, R = P / A

Where P = Predetermined motion time of the element, and

A = Average actual observed time of the element.

The overall rating factor is the mean of rating factors determined for the selected elements. This is applied uniformly to all the manually controlled elements of the work cycle.

**Example**

A work cycle has been divided into 8 elements and time study has been conducted. The average observed times for the elements are given in the following Table:

| Element No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Element Type | M | M | P | M | M | M | M | M |
| Average actual time (minutes) | 0.14 | 0.16 | 0.30 | 0.52 | 0.26 | 0.45 | 0.34 | 0.15 |

M = Manually Controlled, P = Power Controlled

Total observed time of work cycle = 2.32 min.

Suppose we select three elements 2, 5 and 8 (These must be manually controlled elements). By using some PMT system, suppose we determine the times of these elements as

| Elements No. | 2 | 5 | 8 |
|---|---|---|---|
| PMT System times (min) | 0.145 | 0.255 | 0.145 |

Rating factor for element 2 = 0.145 / 0.16 = 90.62 %.

Rating factor for element 5 = 0.255 / 0.26 = 98.08 %.

Rating factor for element 8 = 0.145 / 0.15 = 96.66 %.

The mean of the rating factors of selected elements = 95.12 % or say 95 % is the rating factor that will be used for all the manual elements of the work cycle.

The normal time of the cycle can than be calculated as.

| Element No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Element Type | M | M | P | M | M | M | M | M |
| Average actual time (min) | 0.14 | 0.16 | 0.30 | 0.52 | 0.26 | 0.45 | 0.34 | 0.15 |
| PMT system time (min) | | 0.145 | | | 0.255 | | | 0.145 |
| Performance Rating Factor | 95 | 95 | 100 | 95 | 95 | 95 | 95 | 95 |

Normal Cycle Time

= 0.95(0.14+0.16+0.52+0.26+0.45+0.34+0.15) +1.00(0.30)

=1.92+0.30

=2.22 minutes

It is to be noted that power controlled (or machine-paced) elements are always given 100% rating.

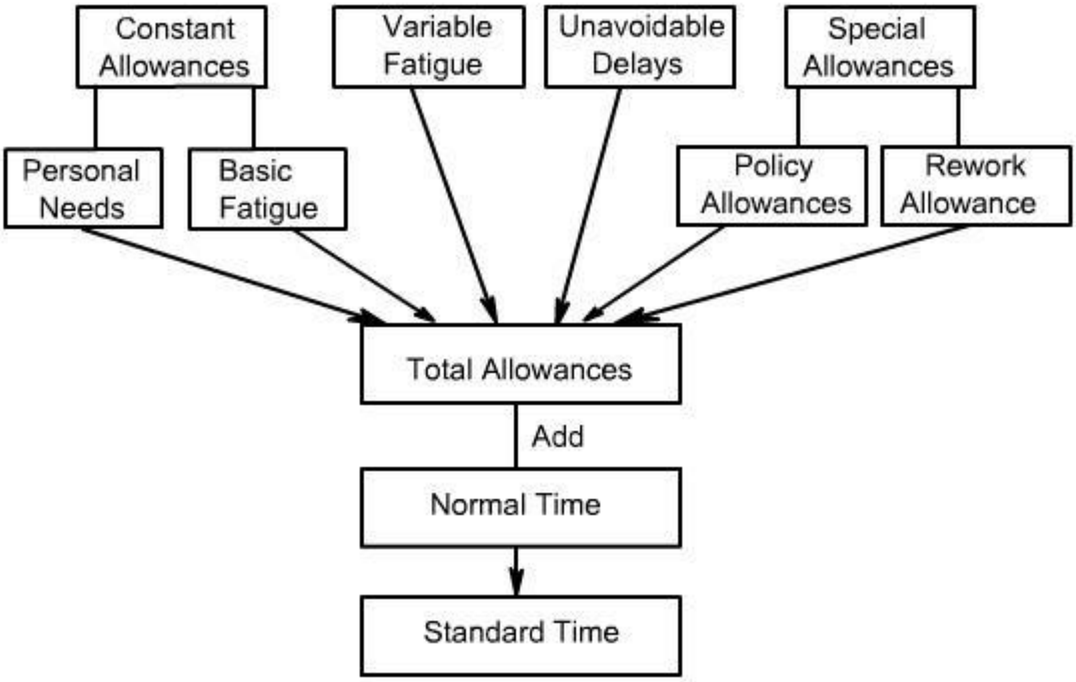
**Allowances**

The readings of any time study are taken over a relatively short period of time. The normal time arrived at, therefore, does not include unavoidable delay and other legitimate lost time, for example, in waiting for materials, tools or equipment; periodic inspection of parts; interruptions due to legitimate personal needs, etc. It is necessary and important that the time study person applies some adjustment, or allowances, to compensate for such losses so that fair time standard is established for the given job.

Allowances are generally applied to total cycle time as some percentage of it, but sometimes these are given separately for machine time as some % and for manual effort time some other %. However, no allowances are given for interruptions which may be due to factors which are within the operator's control or which are avoidable.

Most companies allow the following allowances to their employees.

- Constant allowances (for personal needs and basic fatigue)
- Delay Allowance (for unavoidable delays)
- Fatigue Allowance (for job dependent fatigue)
- Personal Allowance
- Special Allowance




**Delay Allowance**

This time allowance is given to operator for the numerous unavoidable delays and interruptions that he experiences every day during the course of his work. These interruptions include interruptions from the supervisor, inspector, planners, expediters, fellow workers, production personnel and others. This allowance also covers interruptions due to material irregularities, difficulty in maintaining specifications and tolerances, and interference delays where the operator has to attend to more than one machine.

**Fatigue Allowance**

This allowance can be divided into two parts: (i) basic fatigue allowance and (ii) variable fatigue allowance. The basic fatigue allowance is given to the operator to compensate for the energy expended for carrying out the work and to alleviate monotony. For an operator who is doing light work while seated, under good working conditions and under normal demands on the sensory or motor system, a 4% of normal time is considered adequate. This can be treated as a constant allowance.

The magnitude of variable fatigue allowance given to the operator depends upon the severity of conditions, which cause extra (more than normal) fatigue to him. As we know, fatigue is not homogeneous. It ranges from strictly physical to purely psychological and includes combinations of the two. On some people it has a marked effect while on others, it has apparently little or no effect. Whatever may be the kind of fatigue-physical or mental, the result is same-it reduces the work output of operator. The major factors that cause more than just the basic fatigue includes severe working conditions, especially with respect to noise, illumination, heat and humidity; the nature of work, especially with respect to posture, muscular exertion and tediousness, and like that.

It is true that in modern industry, heavy manual work, and thus muscular fatigue is reducing day by day but mechanization is promoting other fatigue components like monotony and mental stress. Because fatigue in totality cannot be eliminated, proper allowance has to be given for adverse working conditions and repetitiveness of the work.

**Personal Allowance**

This is allowed to compensate for the time spent by worker in meeting the physical needs, for instance a periodic break in the production routine. The amount of personal time required by operator varies with the individual more than with the kind of work, though it is seen that workers need more personal time when the work is heavy and done under unfavorable conditions.

The amount of this allowance can be determined by making all-day time study or work sampling. Mostly, a 5 % allowance for personal time (nearly 24 minutes in 8 hours) is considered appropriate.

**Special Allowances**

These allowances are given under certain special circumstances. Some of these allowances and the conditions under which they are given are:

Policy Allowance: Some companies, as a policy, give an allowance to provide a satisfactory level of earnings for a specified level of performance under exceptional circumstance. This may be allowed to new employees, handicap employees, workers on night shift, etc. The value of the allowance is typically decided by management.

Small Lot Allowance: This allowance is given when the actual production period is too short to allow the worker to come out of the initial learning period. When an operator completes several small-lot jobs on different setups during the day, an allowance as high as 15 percent may be given to allow the operator to make normal earnings.

Training Allowance: This allowance is provided when work is done by trainee to allow him to make reasonable earnings. It may be a sliding allowance, which progressively decreases to zero over certain length of time. If the effect of learning on the job is known, the rate of decrease of the training allowance can be set accordingly.

Rework Allowance: This allowance is provided on certain operation when it is known that some percent of parts made are spoiled due to factors beyond the operator's control. The time in which these spoiled parts may be reworked is converted into allowance.

Different organizations have decided upon the amount of allowances to be given to different operators by taking help from the specialists / consultants in the field and through negotiations between the management and the trade unions. ILO has given its recommendations about the magnitude of various allowances, as shown in Table.

**Example:**

In making a time study of a laboratory technician performing an analysis of processed food in a canning factory, the following times were noted for a particular operation.

| Run | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Operation time (sec.) | 21 | 21 | 16 | 19 | 20 | 16 | 20 | 19 | 19 | 20 | 40 | 19 |
| Run | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| Operation time (sec.) | 21 | 18 | 23 | 19 | 15 | 18 | 18 | 19 | 21 | 20 | 20 | 19 |

If the technician's performance has been rated at 120 percent, and the company policy for allowance (personal, fatigue, etc.) stipulates 13 percent,

- Determine the normal time.
- Determine the standard time.

Watch readings falling 50 % above and 25 % below the average may be considered as abnormal.

**Ans:**

$$T_{av} = \frac{\Sigma \text{cycle time}}{\text{No. of cycles}} = \frac{481}{24} = 20.04 \text{ s.}$$

$$1.5\, T_{av} = 30 \text{ s.}$$

$$0.75\, T_{av} = 15 \text{ s.}$$

Discarding the time values which are greater than $1.5\, T_{av}$ or less than $0.75\, T_{av}$,

the average observed cycle time $= \frac{441}{23} = 19.2$ s.

$$\text{Normal time} = 19.2 \times \frac{120}{100} = 23.04 \text{ s.}$$

$$\text{Standard time} = \text{normal time} + \text{allowances}$$

$$= 23.04 \times \frac{100}{100 - 13}$$

$$= 26.5 \text{ seconds.}$$

**Work Sampling**

Work Sampling (also sometimes 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. For example, if 500 instantaneous observations taken at random intervals over a few weeks show that a lathe operator was doing productive work in 365 observations and in the remaining 135 observations he was found 'idle' for miscellaneous reasons, then it can be reliably taken that the operator remains idle (135/500) x 100 = 27 % 0f the time. Obviously, the accuracy of the result depends on the number of observations. However, in most applications there is usually a limit beyond which greater accuracy of data is not economically worthwhile.

Use of Work Sampling for Standard Time Determination

Work sampling can be very useful for establishing time standards on both direct and indirect labor jobs. The procedure for conducting work sampling study for determining standard time of a job can be described step-wise.

Step 1 . Define the problem.

• Describe the job for which the standard time is to be determined.

• Unambiguously state and discriminate between the two classes of activities of operator on the job: what are the activities of job that would entitle him to be in 'working" state.

This would imply that when operator will be found engaged in any activity other than those would entitle him to be in "Not Working" state.

Step 2. Design the sampling plan.

• Estimate satisfactory number of observations to be made.

• Decide on the period of study, e.g. two days, one week, etc.

• Prepare detailed plan for taking the observations.

This will include observation schedule, exact method of observing, design of observation sheet, route to be followed, particular person to be observed at the observation time, etc.

Step 3. Contact the persons concerned and take them in confidence regarding conduct of the study.

Step 4. Make the observations at the pre-decided random times about the working / not working state of the operator. When operator is in working state, determine his performance rating. Record both on the observation sheet.

Step 5. Obtain and record other information. This includes operator's starting time and quitting time of the day and total number of parts of acceptable quality produced during the day.

Step 6. Calculate the standard time per piece.

We will now briefly discuss some important issues involved in the procedure.

Number of Observations

As we know, results of study based on larger number of observations are more accurate, but taking more and more observations consumes time and thus is costly. A cost-benefit trade-off has thus to be struck. In practice, the following methods are used for estimation of the number of observations to be made.

(i) Based on judgment. The study person can decide the necessary number of observations based on his judgment. The correctness of the number may be in doubt but estimate is often quick and in many cases adequate.

(ii) Using cumulative plot of results. As the study progresses the results of the proportion of time devoted to the given state or activity, i.e. Pi from the cumulative number of observations are plotted at the end of each shift or day. A typical plot is shown in Figure. Since the accuracy of the result improves with increasing number of observations, the study can be continued until the cumulative Pi appears to stabilize and collection of further data seems to have negligible effect on the value of Pi.

(iii) Use of statistics. In this method, by considering the importance of the decision to be based on the results of study, a maximum tolerable sampling error in terms of confidence level and desired accuracy in the results is specified. A pilot study is then made in which a few observations are taken to obtain a preliminary estimate of Pi. The number of observations N necessary are then calculated using the following expression.

The number of observations estimated from the above relation using a value of Pi obtained from a preliminary study would be only a first estimate. In actual practice, as the work sampling study proceeds, say at the end of each day, a new calculation should be made by using increasingly reliable value of Pi obtained from the cumulative number of observations made.

Determination of Observation Schedule

The number of instantaneous observations to be made each day mainly depends upon the nature of operation. For example, for non-repetitive operations or for operations in which some elements occur in-frequently, it is advisable to take observations more frequently so that the chance of obtaining all the facts improves. It also depends on the availability of time with the person making the study. In general, about 50 observations per day is a good figure. The actual random schedule of the observations is prepared by using random number table or any other technique.

Design of Observation Sheet

A sample observation sheet for recording the data with respect to whether at the pre-decided time, the specified worker on job is in 'working' state or 'non-working' state is shown in Figure. It contains the relevant information about the job, the operators on job, etc. At the end of each day, calculation can be done to estimate the percent of time workers on the job (on an average) spend on activities, which are considered as part of the job.

Conducting Work Sampling Study

At the predecided times of study, the study person appears at the work site and observes the specific worker (already randomly decided) to find out what is he doing. If he is doing activity which is part of the job, he is ticked under the column 'Working' and his performance rating is estimated and recorded. If he is found engaged in an activity which is not a part of job, he is ticked under the column 'Not Working'. At the end of day, the number of ticks in 'Working' column is totaled and average performance rating is determined.

The observed time (OT) for a given job is estimated as

The normal time (NT) is found by multiplying the observed time by the average performing index (rating factor).

Where = is average rating factor to be determined as , Figure

The standard time is determined by adding allowances to the normal time.

Example

A work sampling study was made of a cargo loading operation for the purpose of developing its standard time. The study was conducted for duration of 1500 minutes during which 300 instantaneous observations were made at random intervals. The results of study indicated that the worker on the job was working 80 percent of the time and loaded 360 pieces of cargo during the study period. The work analyst rated the performance at 90 %. If the management wishes to permit a 13 % allowance for fatigue, delays and personal time, what is the standard time of this operation?

Ans:

Here, total study period = 1500 minutes

Working fraction = 80 percent

Average rating = 90 percent

Number of units loaded = 360

Allowances = 13 %

Advantages and Disadvantages of Work Sampling in Comparison with Time Study.

**<u>Advantages</u>**
Economical
• Many operators or activities which are difficult or uneconomical to measure by time study can readily be measured by work sampling.

• Two or more studies can be simultaneously made of several operators or machines by a single study person. Ordinarily a work study engineer can study only one operator at a time when continuous time study is made.

• It usually requires fewer man-hours to make a work sampling study than to make a continuous time study. The cost may also be about a third of the cost of a continuous time study.

• No stopwatch or other time measuring device is needed for work sampling studies.

• It usually requires less time to calculate the results of work sampling study. Mark sensing cards may be used which can be fed directly to the computing machines to obtain the results just instantaneously.

Flexible

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

7. Operators are not closely watched for long period of time. This decreases the chance of getting erroneous results for when a worker is observed continuously for a long period, it is probable that he will not follow his usual routine exactly during that period.

Less Erroneous

8. Observations may be taken over a period of days or weeks. This decreases the chance of day-to-day or week-to-week variations that may affect the results.

Operators Like It

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

Observers Like It

10. Work sampling studies are less fatiguing and less tedious to make on the part of time study engineer.

Disadvantages

• Work sampling is not economical for the study of a single operator or operation or machine. Also, work-sampling study may be uneconomical for studying operators or machines located over wide areas.

• Work sampling study does not provide elemental time data.

• The operator may change his work pattern when he sees the study person. For instance, he may try to look productive and make the results of study erroneous.

• No record is usually made of the method being used by the operator. Therefore, a new study has to be made when a method change occurs in any element of operation.

• Compared to stop watch time study, the statistical approach of work sampling study is difficult to understand by workers.

Computerized Work Sampling

Use of a computer can save as much as 30 to 40 percent of the total work sampling study cost. This is because too much clerical effort is involved in summarizing work sampling data, e.g. in determining the number of observations required, determining the daily observations required, determining the number of trips to the area being studied per day, determining the time of each observation, calculating the accuracy of results, plotting data on control charts and like that. Computers can be used for mechanization of the repetitive calculations, display of control charts and calculation of daily as well as cumulative results.

**Predetermined Motion Time System**

A predetermined motion time system (PMTS) may be defined as a procedure that analyzes any manual activity in terms of basic or fundamental motions required to perform it. Each of these motions is assigned a previously established standard time value and then the timings for the individual motions are synthesized to obtain the total time needed for performing the activity.

The main use of PMTS lies in the estimation of time for the performance of a task before it is performed. The procedure is particularly useful to those organizations which do not want troublesome performance rating to be used with each study.

Applications of PMTS are for

(i) Determination of job time standards.

(ii) Comparing the times for alternative proposed methods so as to find the economics of the proposals prior to production run.

(iii) Estimation of manpower, equipment and space requirements prior to setting up the facilities and start of production.

(iv) Developing tentative work layouts for assembly lines prior to their working in order to minimize the amount of subsequent re-arrangement and re-balancing.

(v) Checking direct time study results.

A number of PMTS are in use, some of which have been developed by individual organizations for their own use, while other organizations have developed and publicized for universal applications.

Some commonly used PMT systems are:

- Work factor (1938)
- Method Time Measurement (1948)
- Basic Motion Time (1951)
- Dimension Motion Time (1954)

Important considerations which may be made while selecting a PMT system for application to particular industry are:

1. Cost of Installation. This consists mainly of the cost of getting expert for applying the system under consideration.
2. Application Cost. This is determined by the length of time needed to set a time standard by the system under consideration.
3. Performance Level of the System. The level of performance embodied in the system under consideration may be different from the normal performance established in the industry where the system is to be used. However, this problem can be overcome by 'calibration' which is nothing but multiplying the times given in the PMT Tables by some constant or by the application of an adjustment allowance.
4. Consistency of Standards. Consistency of standards set by a system on various jobs is a vital factor to consider. For this, the system can be applied on a trial basis on a set of operations in the plant and examined for consistency in the so obtained operation times.
5. Nature of Operation. Best results are likely to be achieved if the type and nature of operations in the plant are similar to the nature and type of operations studied during the development of the system under consideration.

**Advantages and limitations of using PMT systems**

**Advantages**

Compared to other work measurement techniques, all PMT systems claim the following advantages:

1. There is no need to actually observe the operation running. This means the estimation of time to perform a job can be made from the drawings even before the job is actually done. This feature is very useful in production planning, forecasting, equipment selection, etc.
2. The use of PMT eliminates the need of troublesome and controversial performance rating. For the sole reason of avoiding performance rating, some companies have been using this technique.
3. The use of PMT forces the analyst to study the method in detail. This sometimes helps to further improve the method.
4. A bye-product of the use of PM times is a detailed record of the method of operation. This is advantageous for installation of method, for instructional purposes, and for detection and verification of any change that might occur in the method in future.
5. The PM times can be usefully employed to establish elemental standard data for setting time standards on jobs done on various types of machines and equipment.
6. The basic times determined with the use of PMT system are relatively more consistent.

**Limitations**

There are two main limitations to the use of PMT system for establishing time standards. These are: (i) its application to only manual contents of job and (ii) the need of trained personnel. Although PMT system eliminates the use of rating, quite a bit of judgment is still necessarily exercised at different stages.