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IENG-301
Fundamentals of Work Study and Ergonomics

1. Work Study:

Objectives:

1- The elimination of unnecessary work,
2- The design of methods and procedures which are most effective,
3- The design of methods and procedures which require the least effort,
4- The design of methods and procedures, which are suited to the person who uses them.

The **techniques of Work Study** that will be covered in this course are:

1- Method Study,
2- Charting Techniques,
3- Time Study,
4- Work Place Design principles,
5- Job Evaluation and Compensation.

2. Ergonomics (or Human Factors Engineering):

Objective:

Designing for Human Use.

The **subjects of Ergonomics** that will be covered in this course are:

1- Human physiology and Anthropometry,
2- Fatigue assessment,
3- Fundamentals of Industrial Hygiene,
4- Human Information Retrieval and Control,
5- Fundamental of Industrial product design.

PRODUCTIVITY

Productivity is a term that has a number of different meanings although it is most commonly associated with labor effectiveness in industry.

In a broad sense, productivity is the ratio of output to some or all of the resources used to produce the output.

$$\text{Productivity} = \frac{\text{Output}}{\text{Input}}$$

Examples:

Labor productivity = units produced / hours worked

Capital productivity = output / capital input

Material productivity = output / material input

Increased productivity makes it possible to pay good wages to employees, provide satisfactory dividends to stockholders and to sell products and services at low prices.

Many companies compute their labor productivity index annually and keep a continuous record, making comparisons with other companies in their industry and with the national index.

The ideal objective of an organization might be to provide adequately for employees and stockholders and to sell products at lower and lower prices. This would serve to increase the standard of living and reduce inflation.

Work Study, Definition and scope

Definitions:
1- Motion study: **Work methods design-**for finding the preferred method of doing work. That is, the ideal method or the one nearest to it.
2- Time study: Work measurement- for determining the standard time to perform a specific task.
3- Motion and Time Study: The systematic study of work systems with the purposes of:

1)- developing the preferred system and method, usually the one with the lowest cost;

2)- standardizing this system and method;

3)- determining the time required by a qualified and properly trained person working at a normal pace to do a specific task or operation; and

4)- assisting in training the worker in the preferred method.

1- Developing the Preferred Method (or Work Methods Design).

Every business and industrial organization is concerned with the creation of goods and services in some form- utilizing workers, machines, and materials. In a manufacturing plant (as example), the production process might include the procurement of the raw materials, the machining and fabrication of the parts, and the delivery of the finished product.
In designing, such a manufacturing process, consideration would be given to the entire system and to each individual operation, which would go to make up the system or process.
The design of such a process employs the **general-problem-solving** approach (i.e. the **systematic approach**, or **scientific method**, or **engineering approach**).

Methods design therefore starts with the consideration of the purpose or goal- “to manufacture a specific product”.

Therefore, the objective is to design a system, a sequence of operations and procedures that make up the preferred solution.

Certain tools and techniques have evolved over the years to assist in developing preferred work methods. These are shown in the figure 1, below.

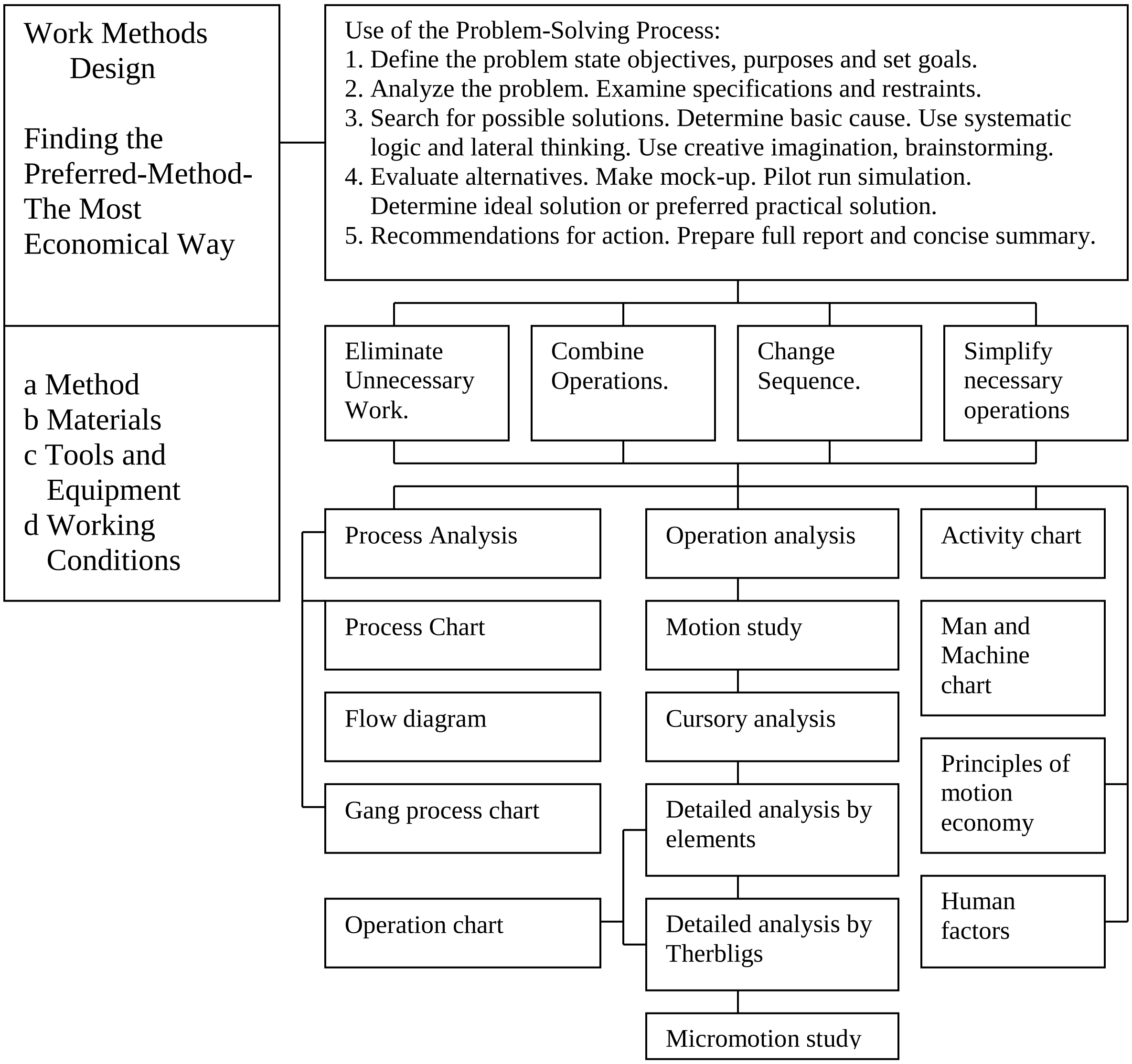

Figure 1. Developing the preferred work methods

2- Standardizing the Operation-Written Standard Practice.

After the best method for doing the work has been determined, this should be standardized. Ordinarily, the work is broken into specific jobs or operations which are described in detail. The particular set of motions, the size, shape, and quality of material, the particular tools, jigs, fixtures, gauges, and the machine or piece of equipment should be definitely specified. All these factors, as well as the conditions should be definitely specified. The conditions surrounding the worker must be maintained after they have been standardized.

A written standard practice giving a detailed record of the operation and specifications for performing the work is the most common way of preserving the standard.

"A job cannot be measured until it has been defined".

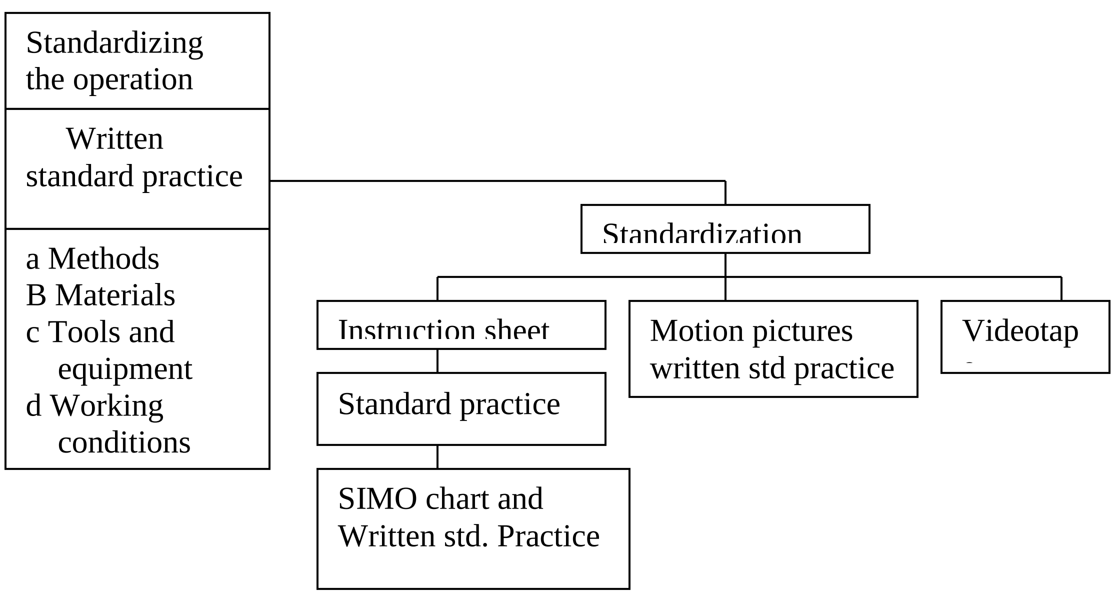

Figure 2. Standardizing the operation

3- Determining the time standard-Work Measurement

Motion and time study may be used to determine the standard number of minutes that a qualified, properly trained, and experienced person should take to perform a specific task or operation when working at a normal pace.

This time standard may be used for **planning** and **scheduling work**, for **cost estimating**, or for **labor cost control**, or it may serve as the basis for a **wage incentive plan**.

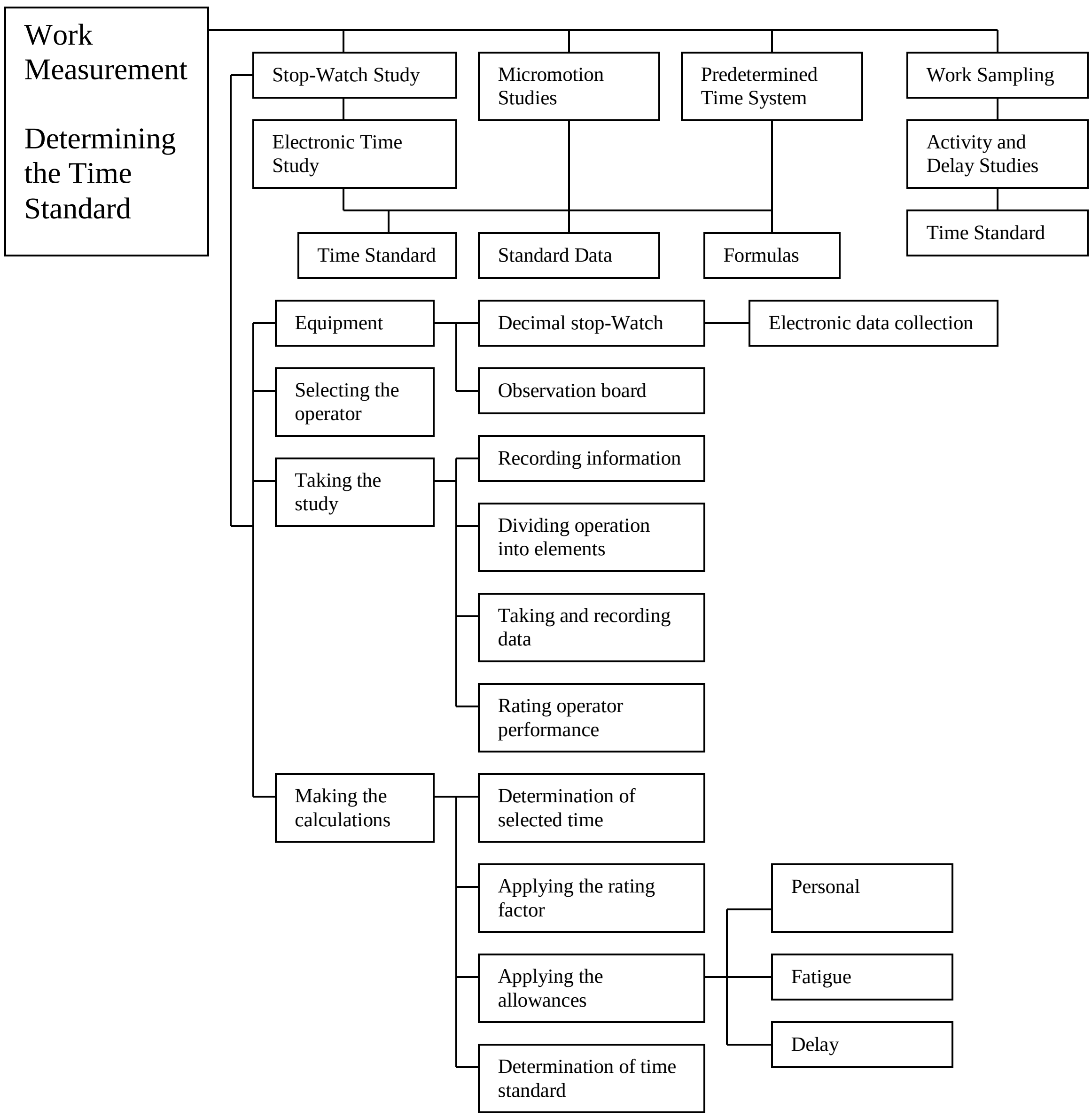

Figure 3. Determination the Time Standard

4. Training the Operator

A carefully developed method of doing work is of little value unless it can be put into effect. It is necessary to train the operator to perform the work in the prescribed manner.

The supervisor, the motion and time study analyst, a special instructor, or a skilled operator may act as the teacher.

The industrial engineers serve as teachers and consultants to supervisors and to worker group.

HISTORY OF MOTION AND TIME STUDY

HISTORICAL DEVELOPMENT

Fredrick W. Taylor,

- He is generally conceded to be the founder of modern 'Time Study.' However, Time studies were conducted in Europe many years before Taylor's time. In 1760, Jean Rodolphe Perronet, a french engineer, made extensive Time Studies in manufacturing, while 60 years later, an english economist, Charles W. Babbage, conducted Time Study in manufacturing.

- Taylor began his Time Study work in 1881 at the Midvale Steel Company in Philadelphia.

- Taylor proposed that the work of each employee be planned out by the Management at least one day in advance. Workers were to receive complete written instructions describing their tasks in detail and noting the means to accomplish them. Each job was to have a Standard Time, determined by Time Studies made by experts.

- In june 1903, at the Saratoga meeting of the American Society of Mechanical Engineers (ASME), Taylor presented his famous paper, 'Shop Management' which included the elements of scientific management: Time Study, Standardization of all tools and tasks, use of planning department, use of slide rules and similar time saving implements, instruction cards for workers, bonuses for successful performance, differential rates, mnemonic systems for classifying products, routing systems, and modern cost systems.

- Taylor's technique were well received by many factory managers.

- In 1917, 59 out of 113 plants that installed this 'Scientific Management' were comletely successful.

- Taylor died in 1915 at the age of 59.

Frank and Lilian Gilbreth,

- They were the founders of the modern Motion Study Technique, which may be defined as the study of the body motions used in performing an operation, to improve the operation by eliminating unnecessary motions, simplifying necessary motions, and then establishing the most favorable motion sequence for maximum efficiency.

- They studied body motions to increase production, reduce fatigue, and instruct operators in the best method of performing an operation.

- They developed the technique of filming motions to study them, in a technique known as Micro-motion Study.

- Additionally, they developed the Cyclegraphic analysis and Chronocyclegraphic Analysis techniques for studying the motion paths made by an operator.

- After the death of Gilbreth (at the age of 55), Lilian, who had received a PhD in Psychology and had been a more than equal collaborator, continued on her own, advancing the concept of work simplification especially for the physically handicapped.

- Lilian was dead in 1972 at the age of 93.

Carl G. Barth,

- Developed a production slide rule for determining the most efficient combinations of speeds and feeds for cutting metals of various hardness, considering the depth of cut, size of tool, and life of the tool.

- Investigated also the number of foot-pounds of work a worker could do ın a 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 effort to inform management of procedures for efficient operation.

- Reorganized the company, integrated its shop procedures, installed standard costs and a bonus plan.

- His effort, resulted in excess of $1.5 mililion.

- His effort was recognized as the term 'Efficiency Engineering.'

<u>Henry Laurence Gantt</u>,

- Developed simple graphs that would measure performance while visually showing projected schedules.

- Invented a Wage Payment sytem 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.

- Emphasized Human Relations and promoted Scientific Managemet as more than an inhuman 'Speed up' of labor.

<u>Motion and Time Study</u> received added stimulus during World War II.

<u>In Summary we may consider the followings;</u>

Frederick W. TAYLOR, originated the **Time study** in year 1881.

Taylor's real contribution to industry was his scientific method, his substitution of fact-finding for rule of thumb procedure.

He understood that he was dealing with a human problem as well as with materials and machines. He approached the human side of his investigations with an understanding of its psychological aspects.

Taylor explained his objectives (known as **Taylor's Principles of Management**) in the following way:

First. The development of a science for each element of a man's work, thereby replacing the old rule of thumb methods.

Second. The selection of the best worker for each particular task and then training, teaching, and developing the workman; in place of the former practice of allowing the worker to select his own task and train himself as best he could.

Third. The development of a spirit of hearty cooperation between the management and the men, in the carrying on of the activities in accordance with the principles of the developed science.

Fourth. The division of the work into almost equal shares between the management and the workers, each department taking over the work for which it is the better fitted; instead of the former condition, in which almost all of the work and the greater part of the responsibility were thrown on the men.

FRANK, B. GILBRETH and his wife LILLIAN, M. GILBRETH, originated the **Motion study**.

Mr. GILBRETH, saw how to make improvement, in methods, by analyzing the motions used by workmen. He substituted shorter and less fatiguing motions for longer and more tiring ones.

The photographs, he made, for his worker in motion, aided him to investigate the motion study.

Mr. and Mrs. GILBRETH, developed the technique of **Micromotion study**.

Micromotion study is the study of the fundamental element or sub-divisions of an operation by means of a motion picture camera and a timing device which accurately indicates the time intervals on the motion picture film.

GILBRETHs were concentrating on finding the very best way for doing work. They wished to determine the shortest possible time in which the work would be performed.
They used timing devices of great precision and selected the best operators obtainable as subjects for their studies.

F. GILBRETH, also, developed two techniques**, cyclegraphic** and **chronocyclegraphic** analysis, for the study of the motion path of an operator.

It is possible to record the path of motion of an operator by attaching a small electric light bulb to the finger, hand, or other part of the body and photographing, with a still camera, the path of light as it moves through space. Such a record is called a **cyclegraph.**

If an interrupter is placed in the electric circuit with the bulb, and if the light is flashed on quickly and off slowly, the path of the bulb will appear as a dotted line with pear-shaped dots indicating the direction of the motion. The spots of light will be spaced according to the speed of the movement, being widely spaced when the operator moves fast and close together when the movement is slow. From this graph it is possible to measure accurately time, speed, acceleration, and retardation, and to show direction and the path of motion in three dimensions. Such a record is called a **chronocyclegraph**. From the **chronocyclegraph**, it is possible to construct accurate wire models of the motion paths. GILBRETH used these records to aid in improving methods, to demonstrate correct motions, and to assist in teaching new operators.

The General Problem-Solving Process

Methods design, is a form of creative problem solving.
The following five steps, of the general problem solving process, are useful in the logical and systematic approach to solving almost any problem.

1. **Problem definition**
2. **Analysis of problem**
3. **Search for possible solutions**
4. **Evaluation of alternatives**
5. **Recommendation for action.**

1.Problem definition

METHODS DESIGN WORKSHEET

Problem Definition-Statement of purpose, goal or objective-Formulation of the problem

a- Criteria-Means of judging successful solution of problem
b- Output requirements:
1) Maximum daily output
2) Seasonal variations
3) Annual volume
4) Expected life of product, shape of volume growth and decline curve

c- Completion date and time available:
1) to design,
2) to install and try out facilities,
3) to bring output up to full production

2. Analysis of the Problem

METHODS DESIGN WORKSHEET

Analysis of Problem (No evaluation is to be made at this step)

1- Specifications or constraints, including any limits on original capital expenditures
2- Description of present method if operation is now in effect. This might include:
   1). Process charts,
   2). Flow diagrams,
   3). Trip frequence diagrams,
   4). Man and machine charts,
   5). Operation charts, and
   6). Simo charts.

3- Determination of activities that man probably can do best and those that the machine can do best and man-machine relationships.
4- Re-examination of problems and determination of subproblems.
5- Re-examination of criteria.

Notes:

Evaluation of the facts should not be made during the analysis stage. Critical judgment should be deferred until later in the problem-solving process.

3. Search for Possible Solutions

The basic objective of course is to find the preferred solution that will meet the criteria and the specifications that have been established.
This suggests that several alternative solutions be found and then the preferred solution can be selected from these.

Note:
It is wise to take a broad and idealistic view in considering possible solutions to the problem.

4. Evaluation of Alternatives

We may have accumulated a large number of ideas bearing on the problem. Some of these can be eliminated rather quickly and the remaining solutions can be considered more carefully.
An examination can be made to determine to what extent each solution meets the criteria and conforms to the original specifications.

It frequently is desirable to select three solutions:

1)- The ideal solution,
2)- the one that is preferred for immediate use, and
3)- possibly another that might be used at some future time or under different condition.

The evaluation of the preferred solution requires careful consideration of future difficulties that might be encountered, such as time and cost to maintain and repair the equipment, the adjustment to widely varying sizes or product mix, etc….

The recommended solution may be the one that is most likely to be accepted and put into effect rather than the ideal solution.

5. Recommendation for Action

In many cases, the person who solves the problem is not the one who will either use the recommended solution or give final approval for its adoption. Therefore, after the preferred solution has been found, it must be communicated to other persons.

The most common form of communication is the written or oral report.

In some cases, a formal and carefully prepared presentation is needed, including the use of charts, diagrams, photographs, three-dimentional models, or working models.
In any event, the presentation should be made in a logical and straitforward manner. It should be easy to follow and to understand. The source of all facts should be indicated, and any assumptions should be clearly stated.

A concise written summary should be a part of every report.

In the industrial situation, the complete cycle might include a follow-up to ensure that the proposed solution has actually been put into effect. Then an audit or a check from time to time might be made to determine what difficulties were being encountered and to evaluate the over-all results of the installation.
It is desirable to know whether the actual operating method is producing the results claimed for it in the proposal.

To continue further, a re-evaluation or restudy of the method might be made with the purpose of finding further possibilities for improvement, and so the problem-solving cycle would be repeated.

In most business and industrial operations there is no final solution to a problem. A given solution may be put into effect and used until a better one can be found.

WORK METHODS DESIGN

The over-all process of putting a new product into production can be divided into three parts or phases:

1. **Planning.**
2. **Pre-production.**
3. **Production.**

1. Planning: There are six basic planning functions.

1)- The design of the product results in drawings showing the size, shape, weight, material, and ultimate use.
2)- The design of the process consists of determining the production system- the operations required and their sequence; dimensions and tolerances, machines, tools, gauges, and equipment required.
3)- The design of work method consists of the establishment of operator-job relationships by determining how the person is to perform the operation, the work place, flow, and economic evaluation.
4)- The design of tools and equipment consists of determining the jigs, fixtures, dies, gauges, tools, and machines which will be needed to perform the operations.
5)- The design of the plant layout consists of determining the total space required in terms of overall location of equipment, stock supply, service centers, work space, material-handling equipment, and the operator-machine relationship.
6)- The determination of the standard time for the operation consists of measuring the work content of the job.

Planning is a decision-making process in that a goal or objective has been determined and a choice has been made from alternatives. The result is a specific product or part and specifications for its actual manufacture.

2. Pre-production

This is the transition phase. The planning information is transferred to the production organization.

Tools, machines, and equipment are purchased, installed, and tried out.

The routing for labor control is released.

Operators are selected and trained for specific tasks.

The planned operator method is carefully checked against the method being used, and the actual time taken is checked against the original estimate.

This is a period during which the individual operations that go to make up the over-all manufacturing activity are tried out.

3. Production

It is the continuing operation of the manufacturing activity established in the planning and pre-production phases.

It involves the use of operators, machines, and materials for the most effective manufacture of the product.

There is necessity of (1) preventing the methods from deteriorating or deviating adversely from the planned methods, and (2) constantly examining the current methods for improvement and, when a better method is found, putting it into effect.

WORK METHODS DESIGN
DEVELOPING A BETTER METHOD

Experience shows that there is no perfect method.

There are always opportunities for improvement.

Search for Possible Solutions-Develop the Preferred Method

The following approaches should be considered in developing possible solutions from which the preferred work method will be selected:

- **A. Eliminate all unnecessary work.**
- **B. Combine operations or elements.**
- **C. Change the sequence of operations.**
- **D. Simplify the necessary operations.**

A. Eliminate all unnecessary work:

In many instances the job or the process should not be a subject for simplification or improvement, but rather it should be eliminated entirely.

The Procter and Gamble Company, established a formal procedure for work elimination, it is called Cost Elimination. This approach goes as follows:

1)- Select the cost for questioning. It is suggested that a major cost should be selected first in order to get the greatest money returns. If the major cost is eliminated, this will often lead to the elimination of many smaller operations as well. Labor costs, materials costs, clerical costs, and overhead costs of all kinds are possible subjects for elimination. Efficient operations can be eliminated just as easily as those not as well done.

2)- Identify the basic cause. A search should be made to determine the basic cause, which makes the cost necessary. The basic cause is that factor which controls the elimination of the cost. The key question is, “this cost could be eliminated if it were not for what basic cause?”
At this stage we do not ask such a question as “Why is this operation necessary?” or “How could this operation be done better?” These questions are avoided because they tend to justify and defend the job’s continued existence. Instead the objective is to find the basic cause.

Operations for which there is no basic cause, or for which a basic cause no longer exists, can be eliminated at once.

3)- Question the basic cause for elimination. If the basic cause has been identified, then it can be questioned in two ways.

a. Disregard the basic cause and consider what would happen if the operation were not done. If the same results or better results can be obtained without the operation, then consideration should be given to eliminating it at once. However, disregarding the basic cause can be dangerous. In this connection it is necessary to consider two points: (1) determine the area of influence of the basic cause and what else might happen if this basic cause were eliminated? And (2) determine the associated "price tag" of the basic cause. Is there a proper return on the money spent to obtain the desired results? If the basic cause cannot be disregarded, the second opportunity for elimination is b.

b. Apply "why?" questioning. If the job under consideration seems to be necessary, can the job immediately preceding it be eliminated, thus perhaps making all succeeding jobs unnecessary? If complete elimination is not possible, try for partial elimination.

It is often desirable to undertake cost elimination on a department-wide or plant-wide basis. Thus several qualified members of supervision working as a group can help identify basic causes of specific costs selected for study.

Benefits of Work Elimination: If a job can be eliminated, there is no need to spend money on installing an improved method. No interruption or delay is caused while the improved method is being developed, tested, and installed. It is not necessary to train new operators on the new method. The problem of resistance to change is minimized when a job or activity that is found to be unnecessary is eliminated.

B. Combine Operations or Elements

It is sometimes possible to make the work easier by simply combining two or more operations, or by making some changes in method permitting operations to be combined.

C. Change the Sequence of Operations

When a new product goes into production it frequently is made in small quantities on an "experimental" basis. Production often increases gradually, and in time output becomes large, but the original sequence of operations may be kept the same as when production was small. For this and for other reasons it is desirable to question the order in which the various operations are performed.

D. Simplify the Necessary Operations

One of the best ways to approach the problem of methods improvement is to question everything about the job- the way the job is being done, the materials that are being used, the tools and equipment, the working conditions, and the design of the product itself.
Assume that nothing about the job is perfect. Begin by asking the questions: What? Who? Where? When? How? Why?

Question each element or hand motion. Just as in an analysis of the process we tried to eliminate, combine, and rearrange the sequence of operations, so in the single operation we try to eliminate motions, combine them, or rearrange the sequence of necessary motions in order to make the job easier.

Tools for Methods Improvement

Because several different methods of visualizing a process or an operation are widely used, each of them will be fully described later. Of course, not all of these different methods would be used on any one job. For example, it may be found that a process chart or flow diagram is all that is needed.

If a single operation is the subject for study, then the operation chart may be used. The activity chart and the man and machine chart are also useful, and occasionally it may be worthwhile to make a micro motion analysis of the job, particularly if the cycle is short and a large number of people are employed on it.

Note: It should be clearly understood, however, that the process chart, flow diagram, activity chart, man and machine chart, operation chart, and simo chart are merely tools to be used as needed.