# ***INDUSTRIAL ENGINEERING LAB*.**

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**MM 75**

## List of experiments:-

1. 1. Determination of time standard for a given job using stopwatch time-study.

2. Preparation of flow process chart, operation process chart and man-machine charts for an existing setup and development of an improved process.

3. Study of existing layout of a workstation with respect to controls and displays and suggesting improved design from ergonomic viewpoint.

4. To carryout a work sampling study.

5. To conduct process capability study for a machine in the workshop.

6. To design a sampling scheme based on OC curve.

7. To conduct Shewart's experiments on known population

8. Generation of random numbers for system simulation such as facility planning, job shop scheduling etc.

## EXPERIMENT NO-1

Object- . Determination of time standard for a given job using stopwatch time-study

Indroduction :-

Work measurement refer to the estimation of standard time, that is the time allowed for completing one piece of job using the given method. This is the time taken by an average experienced worker for the job with provisions for delays beyond the workers control.

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

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.

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.

Objectives and Applications: -

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

- Estimating material machinery and equipment requirements.
- Estimating the 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 use as basis for incentive payment to those direct and in director labor who show greater productivity.

Time Study is the most versatile and the most widely used.

Time Study Equipment :-

The following equipment is needed for time study work.

1. Timing device
2. Time study observation sheet

3. Time study observation board
4. Other equipment

1. Timing Device

The stop watch (Figure1) and the electronic timer are the most widely used timing devices used for time study. The two perform the same function with the difference that electronics timer can measure time to the second or third decimal of a second and can keep a large volume of time data in memory.

2. Time Study Observation Sheet

It is a printed form with space provided for nothing down the necessaryinformation about the operation being studied like name of operation, drawing number, name of the operator, name of time study person, and the date and place of study. Space are provided in the form for writing detailed description of the process (element-wise), recording stop watch readings for each element of the process, performance rating(s) of the operator, and computation Figure 2 Shows a typical time study observation sheet.

1. 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 3near 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 and device like tachometer for checking the speed, etc.

**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 preci9sion desired, and the required level of confidence in the estimated time standards.

**Step 2: Analyse** the operation to determine whether standard method and conditions exist and whether 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 is more than one operator doing the same task.

**Step 4: Record** information about the standard method, operation, operator, product, equipment, quality and conditions.

**Step 5: Divide** the operation into reasonably small elements.

**Step 6: Time** the operator for each of the elements. Record the data for a few number of cycles. Use the data to estimate the total numbers 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:** For each element **calculate** the representative watch time. Multiply it by the rating factory to get normal time.

Normal time = Observed time * Rating factor

Add the normal time of various elements to obtain the normal time for the whole operation.

**Step 9:** Determine allowances for various delays from the company's policy book or by conducting an independent study.

**Step 10:** Determine standard time by adding allowances to the normal time of operation.

Standard time = Normal time + allowances

**Example**

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

| **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 elements number 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(mins)** | 0.145 | 0.255 | 0.140 |

Rating factor for element 2 = 0.145 / 0.16 = **90.06 %.**

Rating factor for element 2 = 0.255 / 0.26 = **98.08 %.**

Rating factor for element 2 = 0.140 / 0.15 = **96.66 %.**

The mean of the rating factors of selected elements = **94.93 %** 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 is calculated as 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(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 | | | 0.14 |
| **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**

## Standard Data Procedure:

In this procedure, we estimate the allowance for arriving the standard data.

### 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 need, 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 as some % for machine time and some other % for manual effort time. However no allowance are given for interruptions which maybe due to factor which are within the operator's control or which are avoidable.

- Delay Allowance
- Fatigue Allowance
- Personal Allowance
- Special Allowance

### Delay Allowance

This time allowance is given to an operator for the numerous 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 the factor or conditions, which cause extra (more than normal) fatigue to him. As we know, fatigue is not homogeneous, it range 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 sever 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. A normal person requires 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 Allowance**

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

**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 maker 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 present 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 .

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,

(i) Determine the normal time.

(ii)Determine the standard time.

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

**Ans :**

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

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

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

Discarding the time values which are greater than $1.5\,T_{av}$ or less than $0.75\,T_{av}$, the average observed cycle time $= \frac{441}{23} = 19.2$ sec.

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

Standard time = normal time + allowances

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

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

Result :- We have studied about time standard for a given job using stopwatch time-study.

EXPERIMENT :-2

Object:- Preparation of flow process chart, operation process chart and man-machine charts for an existing setup and development of an improved process.

**Introduction:-**

**1.1.METHOD STUDY**

Method study is the technique of systematic recording and critical examination of existing and proposed ways of doing work and developing an easier and economical method.

### 1.1.1 Objectives of Method Study

1. Improvement of manufacturing processes and procedures.
2. Improvement of working conditions.
3. Improvement of plant layout and work place layout.
4. Reducing the human effort and fatigue.
5. Reducing material handling
6. Improvement of plant and equipment design.
7. Improvement in the utility of material, machines and manpower.
8. Standardisation of method.
9. Improvement in safety standard.

## 1.2. BASIC PROCEDURE FOR METHOD STUDY

The basic procedure for conducting method study is as follows:

1. Select the work to be studied.
2. Record all facts about the method by direct observation.
3. Examine the above facts critically.
4. Develop the most efficient and economic method.
5. Define the new method.
6. Install the new method
7. Maintain the new method by regular checking.

***1. Select***

While selecting a job for doing method study, the following factors are considered:

*(a)* Economical factors.
*(b)* Human factors.
*(c)* Technical factors.

***Record***

All the details about the existing method are recorded. This is done by directly observing the work. Symbols are used to represent the activities like operation, inspection, transport, storage and delay. Different charts and diagrams are used in recording. They are:

1. **Operation process chart:** All the operations and inspections are recorded.
2. **Flow process chart**
*(a)* Man type All the activities of man are recorded .
*(b)* Material type All the activities of the material are recorded .
*(c)* Equipment type All the activities of equipment or machine are recorded.
3. Two-handed process chart: Motions of both lands of worker are
   Right hand-Left hand chart recorded independently.
4. Multiple activity chart: Activities of a group of workers doing a single job or the activities of a single worker operating a number of machines are recorded.
5. Flow diagram: This is drawn to suitable scale. Path of flow of material in the shop is recorded.
6. String diagram: The movements of workers are recorded using a string in a diagram drawn to scale.

**CHARTS AND DIAGRAMS USED IN METHOD STUDY (TOOLS AND TECHNIQUES)**

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As explained earlier, the following charts and diagrams are used in method study.

1. Operation process chart (or) Outline process chart.
2. 2. Flow process chart.
3. *(a)* Material type
4. *(b)* Operator type
5. *(c)* Equipment type
6. 3. Two-handed process chart. (or) Left hand-Right hand chart
7. 4. Multiple activity chart.
8. 5. Flow diagram.
9. 6. String diagram.
10. **1.3.1 Process Chart Symbols**
11. The recording of the facts about the job in a process chart is done by using standard symbols.
12. Using of symbols in recording the activities is much easier than writing down the facts about the job. Symbols are very convenient and widely understood type of short hand. They save a lot of writing and indicate clearly what is happening.
13. ***1. Operation***
14. A large circle indicates operation. An operation takes place when there is a change in physical or
15. chemical characteristics of an object. An assembly or disassembly is also an operation.
16. When information is given or received or when planning or calculating takes place it is also
17. called operation.
18. ***Example 1.1***
19. Reducing the diameter of an object in a lathe. Hardening the surface of an object by heat
20. treatment.
21. ***2. Inspection***
22. A square indicates inspection. Inspection is checking an object for its quality, quantity or identifications.
23. ***Example 1.2***
24. Checking the diameter of a rod. Counting the number of products produced.
25. ***3. Transport***
26. An arrow indicates transport. This refers to the movement of an object or operator or equipment
27. from one place to another. When the movement takes place during an operation, it is not called
28. transport.
29. ***Example 1.3***
30. Moving the material by a trolley
31. Operator going to the stores to get some tool.

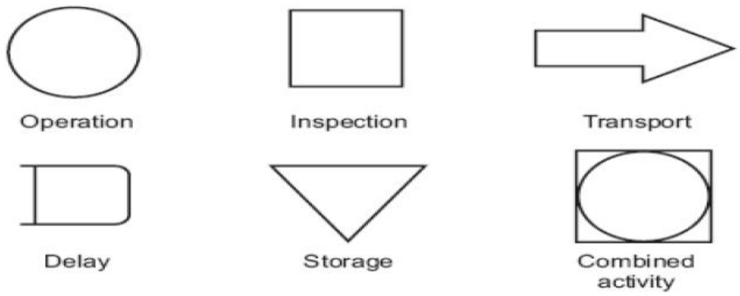



*Fig. 1.1: Process chart symbols*

***4. Delay or temporary storage***

A large capital letter D indicates delay. This is also called as temporary storage. Delay occurs when an object or operator is waiting for the next activity.

***Example 1.4***

An operator waiting to get a tool in the stores. Work pieces stocked near the machine before the next operation.

10 Process Planning and Cost Estimation

***5. Permanent storage***

An equilateral triangle standing on its vertex represents storage. Storage takes place when an object is stored and protected against unauthorized removal.

***Example 1.5***

Raw material in the store room.

***6. Combined activity***

When two activities take place at the same time or done by the same operator or at the same place, the two symbols of activities are combined.

***Example 1.6***

Reading and recording a pressure gauge. Here a circle inside a square represents the combined activity of operation and inspection.

**1.3.2 Operation Process Chart**

An operation process chart is a graphic representation of the sequence of all operations and inspections taking place in a process. It is also known as outline process chart. It gives a bird's eye view of the overall activities. Entry points of all material are noted in the chart.

An example of operation process chart is shown in the figure 1.2. Here the process of manufacture of electric motor is shown.

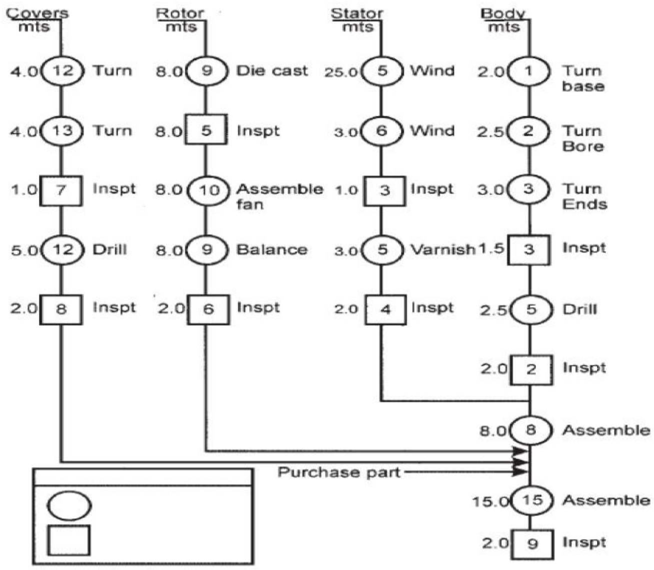



*Fig. 1.2: Operation process chart*

The conventions followed in preparing the chart are
1. Write title at the top of the chart.
2. Begin the chart from the right hand side top corner.
3. Represent the main component at the right extreme.
4. Represent the sequence of operations and inspections by their symbols. Connect them by vertical flow lines.
5. Record the brief description of the activity to the right side of the symbols.
6. Note down the time for each activity to the left of the symbol.
7. Number all operations in one serial order. Start from the right hand top (from number 1).
8. Similarly number all inspections in another serial order (starting from 1).
9. Continue numbering, till the entry of the second component.
10. Show the entry of purchased parts by horizontal lines.

**1.3.3 Flow Process Chart**

A flow process chart is a graphical representation of the sequence of all the activities (operation, inspection, transport, delay and storage) taking place in a process. Process chart symbols are used here to represent the activities. There are three types of flow process charts. They are

***1. Man type flow process chart***

This flow process chart records what the worker does.

***2. Material type flow process chart***

This flow process chart records how the material is handled or treated.

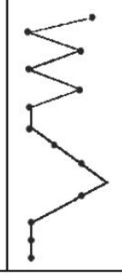
***3. Equipment type flow process chart***

This flow process chart records how the equipment or machine is used.

***Example 1.7***

The activities of a stenographer in preparation of a letter are recorded in the operator type flow process chart shown in figure 1.3.

| | | | | | |
|---|---|---|---|---|---|
| Chart No. : 001 | | Date : | | | |
| Job : Typing A letter | | Charted by: ..................... | | | |
| Chart begins : Steno in her seat | | Chart ends-putting the typed letter in the way | | | |
| Method : Present/Proposed | | | | | |
| *Sl. No.* | *Description of the activities* | *Distance* | *Time in Sec.* | *Symbols* | *Remarks* |
| | | | | O □ ⇒ D ∇ | |
| 1. | Steno in her seat | - | - | | |
| 2. | Hears the bell | - | 3 | | |
| 3. | Goes to manager's room | 6m | 10 | | |
| 4. | Takes down dictation | - | 120 | | |
| 5. | Returns to her seat | 6m | 10 | | |
| 6. | Prepares typewriter | - | 15 | | |
| 7. | Types the letter | - | 150 | | |
| 8. | Checks the matter | - | 40 | | |
| 9. | Goes to manager's room | 6m | 10 | | |
| 10. | Waits till the manager signs | - | 20 | | |
| 11. | Returns to her seat | 6m | 10 | | |
| 12. | Types envelope | - | 20 | | |
| 13. | Puts the letter inside envelope | - | 5 | | |
| 14. | Puts the envelope in dispatch tray | - | 5 | | |



The chart records the activities of the steno. Here, the manager calls the steno and dictates a letter. The steno takes notes of the letter, types it, gets the signature of the manager and sends it for dispatching. These activities are shown in the chart. This is operator type flow process chart. Considering the message in the letter as material, we can prepare the material type flow process chart.

**General guidelines for making a flow process chart**

1. The details must be obtained by direct observation—charts must not be based on memory.
2. All the facts must be correctly recorded.
3. No assumptions should be made.
4. Make it easy for future reference.
5. All charts must have the following details:

*(a)* Name of the product, material or equipment that is observed.
*(b)* Starting point and ending point.
*(c)* The location where the activities take place.
*(d)* The chart reference number, sheet number and number of total sheets.
*(e)* Key to the symbols used must be stated.

**1.3.4 Two-Handed Process Chart (or) Right Hand, Left Hand Chart**

- It is the process chart in which the activities of two hands of the operator are recorded.
- It shows whether the two hands of the operator are idle or moving in relation to one another, in a timescale.
- It is generally used for repetitive operations.

**Operation:** Represents the activities grasp, position, use, release etc. of a tool, component or material.
**Transport:** Represents the movement of the hand or limb to or from the work or a tool or material.
**Delay:** Refers to the time when the hand or limb is idle.
**Storage (Hold):** The term _hold‘ is used here instead of storage. This refers to the time when the work is held by hand.
The activity _inspection‘ by hand is considered as an operation. Hence, the symbol for inspection is not used in this chart.
Two-handed process chart can be used for assembly, machining and clerical jobs.

**General guidelines for preparing the chart**

1. Provide all information about the job in the chart.

2. Study the operation cycle a few times before starting to record.
3. Record one hand at a time.
4. First record the activities of the hand which starts the work first.
5. Do not combine the different activities like operations, transport etc.

***Example 1.8***

Example of a two-handed process chart is shown in figure 1.4. Here the assembly of a nut and washer over a bolt is recorded.

The work place layout is shown in the right hand corner. The activities of left hand are recorded at left half of the chart. The activities of the right hand are recorded at the right half of the chart.

| | | | |
|---|---|---|---|
| Job : Assembly of washer and nut to a bolt | | | |
| Chart begins : Both hands free before assembly | | Assembly Bolt Washer Nut | |
| Chart ends : Both hands free after assembly | | | |
| Chart : Existing method/Proposed method | | Date : | Operator |
| Operator : | | Chart No : | |

| Left hand | | | Right hand | | |
|---|---|---|---|---|---|
| *Sl. No.* | *Description of the activities* | *Symbols* O ⇒ ∇ | *Sl. No.* | *Description of the activities* | *Symbols* O ⇒ ∇ |
| 1. | To the bolt tray | | 1. | To the washer tray | |
| 2. | Picks up one bolt | | 2. | Picks up one washer | |
| 3. | Returns to original position | | 3. | Returns to the initial position | |
| 4. | Holding the bolt | | 4. | Assembles washer over bolt | |
| 5. | Idle | | 5. | To the nut tray | |
| 6. | Idle | | 6. | Picks up one nut | |
| 7. | Idle | | 7. | Returns to initial position | |
| 8. | Idle | | 8. | Assemble nut to the bolt | |
| 9. | To the assembly tray | | 9. | Idle | |
| 10. | Puts the bolt in the tray | | 10. | Idle | |
| 11. | Returns to the original position | | 11. | Idle | |

The horizontal lines represent the time scale. Activities of left hand and right hand shown in the same line occur at the same moment.

Summary of the number of each activity can be tabulated at the bottom of the chart. The chart is first drawn for the existing method. This chart is analysed and if it is found that one hand is over loaded than the other, modification are done in the layout of the workplace or in the sequence of activities. Then a new chart is made for the proposed cycle.

**1.3.5 Man-Machine Chart**

A man-machine chart is a chart in which the activities of more than one worker or machine are recorded. Activities are recorded on a common time scale to show the inter-relationship. It is also known as multiple activity chart.

It is used when a worker operates a number of machines at a time. It is also used when a number of workers jointly do a job.

Activities of workers or machines are recorded in separate vertical columns (bars) with a horizontal time scale.

The chart shows the idle time of the worker or machine during the process.By carefully analyzing the chart, we can rearrange the activities. Work load is evenly distributed among the workers or machines by this the idle time of worker or machine is reduced. Multiple activity chart is very useful in planning team work in production or maintenance. Using the chart we can find out the correct number of machines that a worker can operate at a time. We can also find out the exact number of workers needed to do a job jointly.

To record the time, ordinary wrist watch or stop watch is used. High accuracy is not needed. Man-machine chart is a type of multiple activity chart. Here, the activities of a number of machines are recorded.

An example of man-machine chart is shown in figure 1.5. Here one operator two semi-automatic machines simultaneously. The activities of the operator is recorded in a separate vertical column. The activities of the two machines are recorded in two separate vertical columns. The different activities like loading, machining and unloading are represented by different symbols. Blank space shows the idle time.

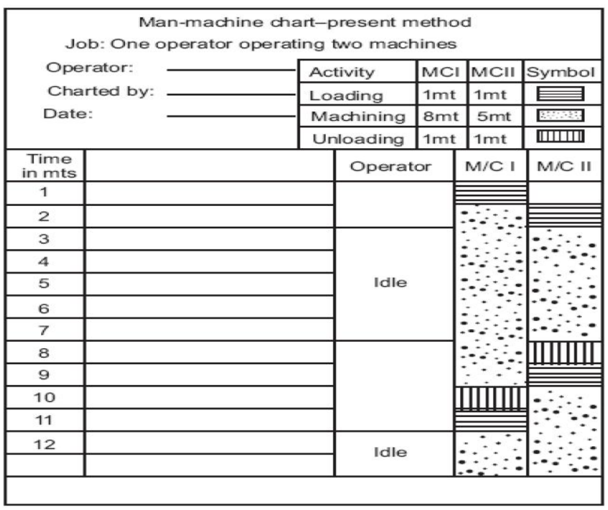



*Fig. 1.5: Man-machine chart*

### 1.3.6 Flow Diagram

In any production shop, repair shop or any other department, there are movements of men and material from one place to another. Process charts indicate the sequence of activities. They do not show the frequent movements of men and material. If these movement are minimized, a lot of savings can be achieved in cost and effort. If the path of movement of material is not frequent and simple, a flow diagram is used for recording the movement.

A flow diagram is a diagram which is drawn to scale. The relative position of machineries, gang ways, material handling equipment etc. are drawn first. Then the path followed by men or material is marked on the diagram. Different movements can be marked in different colours. Process symbols are added to the diagram to identify the different activities at different work centres

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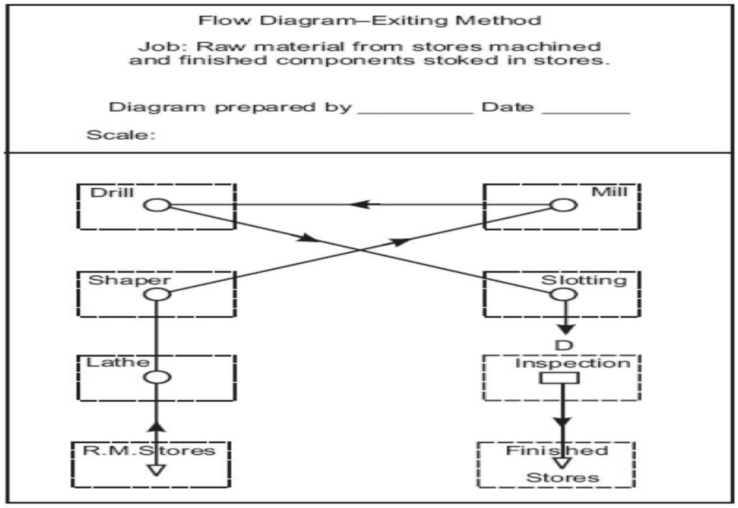



*Fig. 1.6: Flow diagram*

The flow diagram are used for the following purposes:

1. To remove unwanted material movement.
2. To remove back tracking.
3. To avoid traffic congestion.

4. To improve the plant layout. Other informations like location, name of the shop, name of the person drawing the diagram

1. are also given.
2. 3. The path followed by the material is shown by a flow line.
3. 4. Direction of movement is shown by small arrows along the flow lines.
4. 5. The different activities are represented by the symbols on the flow lines. (Same symbols used in flow process chart are used here).
5. 6. If more than one product is to be shown in the diagram different colours are used for each
6. path.
7. 
8. RESULT- We have studied to Prepare flow process chart, operation process chart and man-machine charts for an existing setup and development of an improved process.

9.

EXPERIMENT NO:-3

**Object:-** Study of existing layout of a workstation with respect to controls and displays and suggesting improved design from ergonomic viewpoint.

**Introduction:-**

**ERGONOMICS**

Ergons means _work' and Nomos means _Natural laws'. Ergonomics or its American equivalent _Human Engineering may be defined as the scientific study of the relationship between man and his working environments. Ergonomics implies _Fitting the job to the worker'. Ergonomics combines the knowledge of a psychologist, physiologist, anatomist, engineer, anthropologist and a biometrician.

**1.14.1 Objectives**

The objectives of the study of ergonomics is to optimize the integration of man and machine in order to increase work rate and accuracy. It involves

1. The design of a work place befitting the needs and requirements of the worker.
2. The design of equipment, machinery and controls in such a manner so as to minimize mental and physical strain on the worker thereby increasing the efficiency, and
3. The design of a conductive environment for executing the task most effectively.

Both work study and Ergonomics are complementary and try to fit the job to the workers; however Ergonomics adequately takes care of factors governing physical and mental strains.

**1.14.2 Applications**

In practice, ergonomics has been applied to a number of areas as discussed below

1. Working environments 2. The work place, and 3. Other areas.

***Work place layout***

**Design considerations**

*(a)* Materials and tools should be available at their predetermined places and close to the worker.
*(b)* Tools and materials should preferably be located in the order in which they will be used.
*(c)* The supply of materials or parts, if similar work is to be done by each hand, should be duplicated. That is materials or parts to be assembled by right hand should be kept on right hand side and those to be assembled by the left hand should be kept on left hand side.
*(d)* Gravity should be employed, wherever possible, to make raw materials reach the operator and to deliver material at its destination (e.g., dropping material through a chute).
*(e)* Height of the chair and work bench should be arranged in a way that permits comfortable work posture. To ensure this

- Height of the chair should be such that top of the work table is about 50 mm below the elbow level of the operator.
- Height of the table should be such that worker can work in both standing and sitting positions.
- Flat foot rests should be provided for sitting workers.
- Figure 1.12 shows the situation with respect to bench heights and seat heights.

• The height and back of the chair should be adjustable.
• Display panel should be at right angles to the line or sight of the operator.
*(f)* An instrument with a pointer should be employed for check readings where as for quantitative readings, digital type of instrument should be preferred.
*(g)* Hand tools should be possible to be picked up with least disturbance or rhythm and symmetry of movements.
*(h)* Foot pedals should be used, wherever possible, for clamping declamping and for disposal of finished work.
*(i)* Handles, levers and foot pedals should be possible to be operated without changing body position.
*(j)* Work place must be properly illuminated and should be free from glare to avoid eye strain.
*(k)* Work place should be free from the presence of disagreeable elements like heat, smoke, dust, noise, excess humidity, vibrations etc.

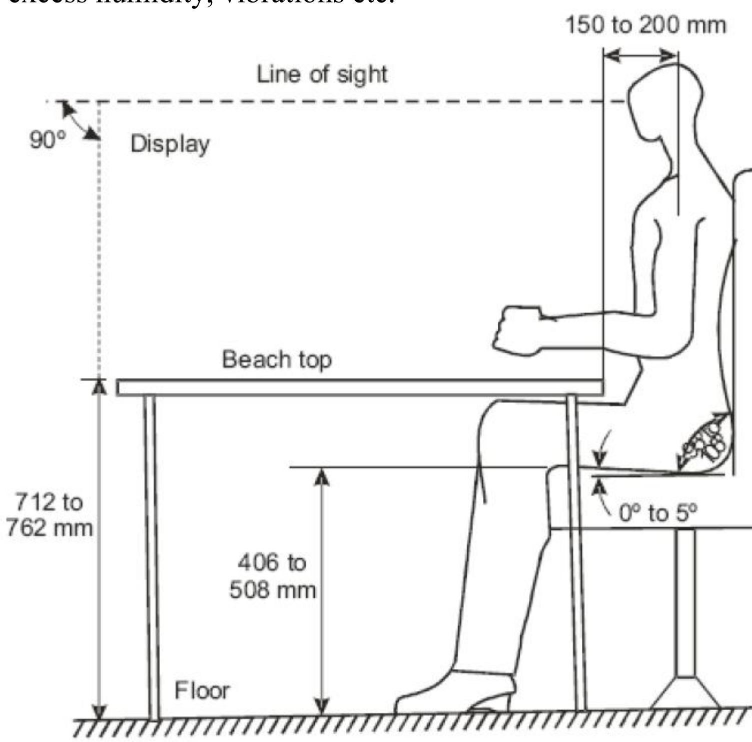


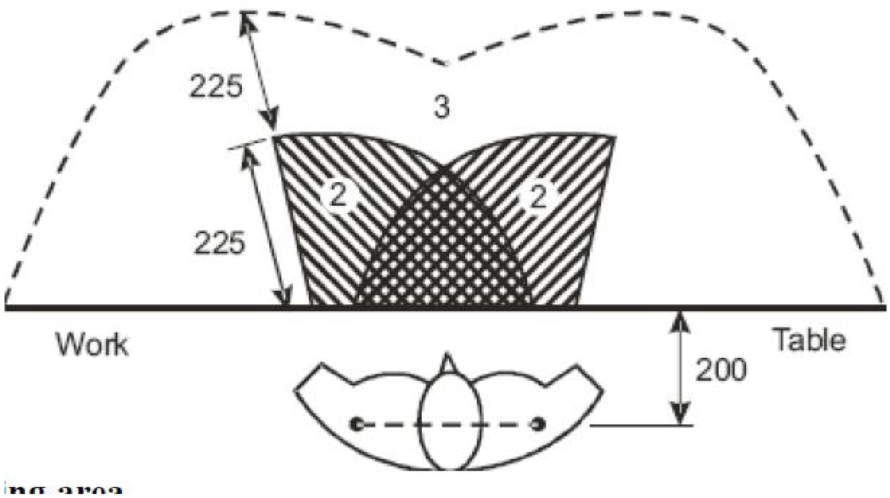

*Fig. 1.12: Bench and seat heights*

**Suggested work place layout**

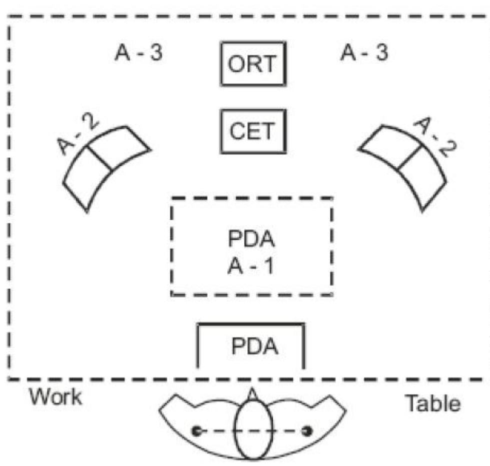
Figure 1.13 shows a work place layout with different areas and typical dimensions. It shows the left hand covering the maximum working area and the right hand covering the normal working area.

**Normal working area**

It is within the easy reach of the operator.




**Maximum working area**
It is accessible with full arm stretch. Figure 1.14 shows work place layout for assembling small component parts. A-1 is the actual working area and the place of assembly (POA) where four component parts P-1, P-2, P-3, and P-4 are assembled together. Bins containing P-1, P-2, P-3, and P-4 and commonly employed tools (CET) (like screw driver, plier, etc.) lie in the normal working area A-2.
ORT




*ig. 1.14: Work place layout for an assembly job*

Occasionally required Tools (ORT) (hammers etc.) lie in the maximum working area A- 3. After the assembly has been made at POA, it is dropped into the cut portion in the work table – PDA (Place for dropping assemblies) from where the assembly is delivered at its destination with the help of a conveyer. This work place arrangement satisfies most of the principles of motion economy.

***3. Other areas***

Other areas include studies related to fatigue, losses caused due to fatigue, rest pauses, amount of energy consumed, shift work and age considerations.
RESULT:_ We have studied existing layout of a workstation with respect to controls and displays and suggesting improved design from ergonomic viewpoint.

## EXPERIMENT NO - 4

Object:- To carryout a work sampling study.
**Introduction:- 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 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.

## Sampling Procedure:

**Step 1**. Define the problem. (i) Describe the job for which the standard time is to be determined. (ii) Unambiguously State and discriminate between the two classes of activities of operator on the job: what are the activities of job with which if operator is found engaged 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. (i) Estimate satisfactory number of observations to be made. (ii) Decide on the period of study, e.g. two days, one week, etc. (iii) Prepare detailed plan for taking the observations. This will include observation schedule, exact method of observing, design of observation sheet route to be followed, the particular person to be observed at the observation time, etc.

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

**Step 4**. Collect the data at the pre-decided random times.

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

**Number of Observations**

As we know, result of study based on larger number of observations are more accurate, but taking more and more observation consume 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 observation 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 adequate in many cases.

(ii) **Using cumulative plot of results**. As the study progresses the results (of the proportion of time devoted to the given 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 Figure4. Since the accuracy of the result improves with increasing number of observation, 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 important 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

$$S.P_i = \chi\sqrt{\frac{P_i(1-P_i)}{N}}$$

Where **S** = desired relative accuracy

**Pi** = estimate of proportion of time devoted to activity expressed as a decimal, e.g. 5 % = 0.05

$\chi$ = a factor depending on the confidence level.

$\chi$ = 1, 2, 3 for confidence levels of 68 %, 95 % and 99 %respectively.

N= No of obeservations needed

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 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 exact (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 worker on job is in 'working' state or 'non-working' state is shown in figure5. It contains the relevant information about the job, the operators on job, etc. At the end of each day, calculation can be done on the percent of time workers on the job (on an average) spend on activities, which are considered as part of the work method.

**Standard Time Determination:-** In this method of work measurement, the observed time for a given job is estimated as the working time divided by the number of units produced during that time.

$$OT = \frac{T \times \left( \eta_i / \eta \right)}{N}$$

Where **T** = Total study period

**N** = Number of units produced in study period

$\eta$= Total number of observations made in study period

$\eta_i$ =Number of observations in which worker(s) was found in 'working' state

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

$$NT = OT \times \left( \bar{R} / 100 \right)$$

Where $\bar{R}$ = Average rating factor = $\sum R / \eta_i$

Finally, the standard time is found 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 minutes during which 3000, 1500 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 period = 1500 minutes

Working fraction = 80 percent

Average rating = 90 percent

Number of units loaded = 360

Allowances = 13 %

Solution:

$$\text{Normal Time} = \frac{\text{Total time} \times \text{Working fraction}}{\text{Number of units}} \times \text{Performance rating}$$

$$= \frac{1500 \times 0.80}{360} \times 0.90 = 3.00 \text{ min.}$$

$$\text{Standard Time} = \text{Normal time} \times \frac{100}{100 - \%\text{ allowances}}$$

$$= 3.00 \times \frac{100}{100 - 13} = 3.45 \text{ min.}$$

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

**Advantage**

*Economical*

1. Many operators or activities are difficult or uneconomical to measure by time study can readily be measured by work sampling.
2. Two or more studies can be simultaneously made of several operators or machines by a single observer. Ordinarily a work study engineer can study only one operator at a time when continuous time study is made.
3. 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.
4. No stopwatch or other time measuring device is needed for work sampling studies.
5. 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.

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.

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.

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.

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

11. Work sampling is applicable to a wide variety of situations in manufacturing, distribution, or service industries.

12. Work sampling is useful when determine the nature of the distribution of work activities within a gang operation.

**Disadvantage**

1. 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.
2. Work sampling study does not provide elemental time data.
3. The operator may change his work pattern when he sees the observer. For instance, he may try to look productive and make the results of study erroneous.
4. 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.
5. Compared to stop watch time study, the statistical approach of work sampling study is difficult to understand by workers.

**<u>Computerized Work Sampling</u>**

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 made use 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 performing it. Each of these motions is assigned a previously established standard time value in such a way that the timings for the individual motions can be synthesized to obtain the total time for the performance of 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 some organizations because it does not require troublesome rating 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 line prior to their working.

(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 publicized for universal applications.

The following are commonly used PMT systems

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

Some important factors which be considered 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 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 among them.
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

### Advantage

Compared to other work measurement techniques, all PMT system 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 PM times 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 time 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.

7. **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.

**RESULT:-** We have studied about work sampling.

# EXPERIMENT NO-5

**Object:-** To conduct process capability study for a machine in the workshop.

**Introduction:-** A process is a unique combination of tools, materials, methods, and people engaged in producing a measurable output; for example a manufacturing line for machine parts. All processes have inherent statistical variability which can be evaluated by statistical methods.

The Process Capability is a measurable property of a process to the specification, expressed as a process capability index (e.g., $C_{pk}$ or $C_{pm}$) or as a process performance index (e.g., $P_{pk}$ or $P_{pm}$). The output of this measurement is usually illustrated by a histogram and calculations that predict how many parts will be produced out of specification (OOS).
Process capability is also defined as the capability of a process to meet its purpose as managed by an organization's management and process definition structures ISO 15504.
Two parts of process capability are: 1) Measure the variability of the output of a process, and 2) Compare that variability with a proposed specification or product tolerance.

**Measure the process:-**

The input of a process usually has at least one or more measurable characteristics that are used to specify outputs. These can be analyzed statistically; where the output data shows a normal distribution the process can be described by the process mean (average) and the standard deviation.

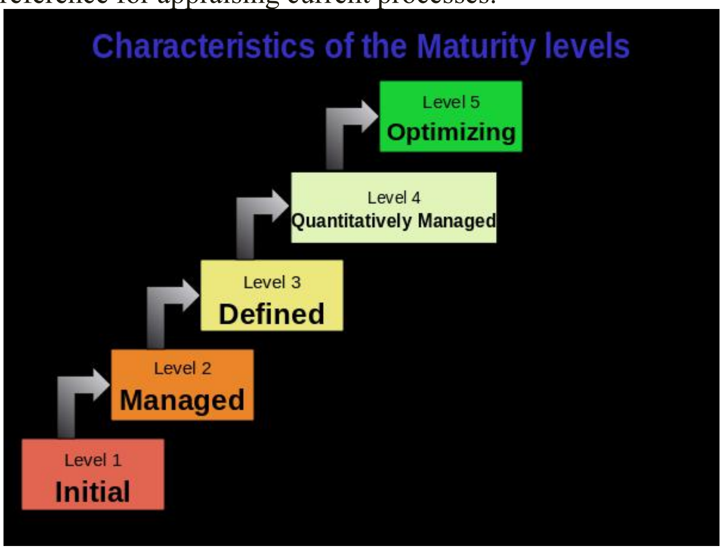
A process needs to be established with appropriate process controls in place. A control chart analysis is used to determine whether the process is "in statistical control". If the process is not in statistical control then capability has no meaning. Therefore the process capability involves only common cause variation and not special cause variation.
A batch of data needs to be obtained from the measured output of the process. The more data that is included the more precise the result, however an estimate can be achieved with as few as 17 data points. This should include the normal variety of production conditions, materials, and people in the process. With a manufactured product, it is common to include at least three different production runs, including start-ups.

The process mean (average) and standard deviation are calculated. With a normal distribution, the "tails" can extend well beyond plus and minus three standard deviations, but this interval should contain about 99.73% of production output. Therefore for a normal distribution of data the process capability is often described as the relationship between six standard deviations and the required specification.

**Capability study:-**

The output of a process is expected to meet customer requirements, specifications, or product tolerances. Engineering can conduct a process capability study to determine the extent to which the process can meet these expectations.
The ability of a process to meet specifications can be expressed as a single number using a process capability index or it can be assessed using control charts. Either case requires running the process to obtain enough measurable output so that engineering is confident that the process is stable and so that the process mean and variability can be reliably estimated. Statistical process control defines techniques to properly differentiate between stable processes, processes that are drifting (experiencing a long-term change in the mean of the output), and processes that are growing more variable. Process capability indices are only meaningful for processes that are stable (in a state of statistical control).
For Information Technology, ISO 15504 specifies a process capability measurement framework for assessing process capability. This measurement framework consists of 5.5+0.5 levels of process capability from none (Capability Level 0) to optimizing processes (CL 5). The measurement framework has been generalized so that it can be applied to non IT processes. There are currently two process reference models covering software and systems. The Capability Maturity Model in its latest version (CMMI continuous) also follows this approach.

**Capability Maturity Model Integration (CMMI) :-**
is a process improvement approach whose goal is to help organizations improve their performance. CMMI can be used to guide process improvement across a project, a division, or an entire organization. Currently supported is CMMI Version 1.3. CMMI in software engineering and organizational development is a process improvement approach that provides organizations with the essential elements for effective process improvement. CMMI is registered in the U.S. Patent and Trademark Office by Carnegie Mellon University.
According to the Software Engineering Institute (SEI, 2008), CMMI helps "integrate traditionally separate organizational functions, set process improvement goals and priorities, provide guidance for quality processes, and provide a point of reference for appraising current processes.




**Overview:-** CMMI currently addresses three areas of interest:
1. Product and service development — CMMI for Development (CMMI-DEV),
2. Service establishment, management, and delivery — CMMI for Services (CMMI-SVC), and
3. Product and service acquisition — CMMI for Acquisition (CMMI-ACQ).
4.

CMMI was developed by a group of experts from industry, government, and the Software Engineering Institute (SEI) at Carnegie Mellon University. CMMI models provide guidance for developing or improving processes that meet the business goals of an organization. A CMMI model may also be used as a framework for appraising the process maturity of the organization.[1]

CMMI originated in software engineering but has been highly generalised over the years to embrace other areas of interest, such as the development of hardware products, the delivery of all kinds of services, and the acquisition of products and services. The word "software" does not appear in definitions of CMMI. This generalization of improvement concepts makes CMMI extremely abstract.

**Conducting a Process Capability Study:--**

**The steps for conducting a process capability study are:**
1. Preparing for the study.
2. Determining the process output.

3. Comparing the output to the spec.
4. Taking action to improve the process.

**A process capability study measures the capability of a specific piece of equipment or a process under specific operating conditions.**

- It is important to identify and record this information prior to the beginning of the process capability study.

**Step 1: Preparing for the Study**

**To prepare for the study:**

- Define the processing conditions.
- Select a representative operator.
- Assure sufficient raw materials are available.
- Make sure the measurement system is reliable.

**Step 2: Determining the Process Output**

**To determine the process output, run the process and collect data as you would if you were setting up a control chart.**

- Make sure the process is stable using the same methods as for setting up a control chart.
- Since common process capability calculations are based on a stable, normally distributed process, if the process is not stable, you should not conduct a process capability study.
- Calculate the process mean and process variation for the measured output.

**Step 3: Comparing Process Output to the Spec**

**A specification normally consists of the nominal, or ideal, measure for the product and the tolerance, which is the amount of variation acceptable to the customer. It is often referred to as "the spec."**

- The distance between the upper spec limit (USL) and the lower spec limit (LSL) is called the total tolerance, or T.T.
- The Cpk for a process is determined by calculating the Cpu and the Cpl. The Cpk is the lower of those two numbers.

**Step 4: Taking Action to Improve the Process**

- There are a variety of activities that can be undertaken to improvement process such as 8D Problem Solving or Mistake-Proofing.
- **More Capability Indices**
- **Over the last several years, some new process capability indices have surfaced. These indices are the Pp, Ppk, Cpm, and Ppm.**
- **Pp and Ppk are called Process Performance Indicators.**
- As their description implies, Pp and Ppk look at what the performance could be. Some people refer to them as short-term capability indices because they do not look at process variation over time.
- Another use of the Process Performance Indicators today is to get a look at how the total variation from the process compares to the specification. Even special causes are included in the determination of total variation.
- Editorial Note: We believe that the inclusion of special causes creates some problems for these indicators. Per AIAG manuals, Pp and Ppk are based on a "statistically stable" process with process data that form "an approximately normal distribution." In our view, it is hard to see how a process can be statistically stable while having special causes of variation; we suggest Ppk and Pp are best used as preliminary process performance indicators.
- The formulas for Pp and Ppk are quite similar to those for Cp and Cpk. The big difference between them is how we calculate the sample standard deviation, s.
- **For Pp and Ppk, the sample standard deviation, s, is calculated directly from the data using:**

$$s = \sqrt{\frac{\sum \left(X - \overline{X}\right)^2}{n-1}}$$

where $X$ = individual data values

$\overline{X}$ = mean of the individual values

$n$ = number of values in the data set

- **For Cp and Cpk, s is calculated by using R-bar/d2.**
- Typically there will be less sources of variation represented in a preliminary process performance study than in a process capability study so the preliminary Ppk value is usually greater than the Cpk value for a process.
- **Cpm is the process capability measured against performance to a target.**
- The Cpm capability index compares the width of the specification to the spread of the process output plus an error term for how far the center of the distribution is from the target.
- The process is penalized for not running on-target. And since the difference-from-target term is squared in the calculation, as the distance from the target increases, the penalty increases dramatically.
- For a centered process that is on-target (that is, the center of the specification is the target), Cp, Cpk, and Cpm will be equal. When close to center, we often find that the Cpk and Cpm values are similar. But if the mean is more than one standard deviation away from the target, then the three indices will give us very different views of the process capability.
- **Ppm is a process performance index based on Cpm.**
- Like Pp and Ppk, Ppm uses the standard deviation equation, and not subgroups, to calculate s.

**Process Capability Study Complications**

**Some of the complications we may be faced with while conducting capability studies include:**

- Using Individual Data, not Subgroups
- Handling One-Sided Tolerances
- Handling Short-Run Processes
- Dealing with Tool Wear Issues
- Dealing with Skewed Distributions
- Not Knowing What the Spec Should Be
- Assessing True Position Capability

**Six Sigma Capability**

**Six Sigma is a broad business approach to drive defects produced by all processes down into parts per million levels of performance.**

- This means it's really about improving the process capability for all critical-to-quality (CTQ) characteristics from all processes in the organization.
- The goal in a Six Sigma organization is to achieve defect levels of less than 3.4 parts per million for every process in the organization and for every CTQ characteristic produced by those processes.

**Six Sigma has been accepted to mean a 4.5-sigma process, not "true six sigma" process.**

- A process that operates with "true six sigma" performance takes up 50% of the specification if centered. This gives it a Cpk and a Cp of 2.0. A process such as this will produce defects at a rate of only ~2 parts per billion.
- Six Sigma professionals have allowed for the process to drift by up to 1.5 standard deviations from the mean. So if we have a process with a Cp = 2.0 but allow for a 1.5s drift, then we have the equivalent of a 4.5 sigma process.

That is, the mean will be 4.5s from the specification limit at the edges of the drift. A 4.5 sigma process yields a 3.4 ppm defect level.

**Instead of Cp and Cpk, some Six Sigma organizations report capability in terms of Z-values.**

- The Z-values represent the number of standard deviation units the mean is away from the specification limits.
- Zl is the distance from the mean to the lower spec and Zu is the distance from the mean to the upper spec.
- Zl equals 3 times Cpl and Zu equals 3 times Cpu. For example, if the Cpl of a process was 1.5, the Zl would be 4.5.

## Experiment NO:-6

**Object:-** To conduct Shewart's experiments on known population.

Introduction:-

Control charts, also known as Shewhart charts or process-behaviour charts, in statistical process control are tools used to determine whether a manufacturing or business process is in a state of statistical control.

**Overview:-** If analysis of the control chart indicates that the process is currently under control (i.e. is stable, with variation only coming from sources common to the process) then no corrections or changes to process control parameters are needed or desirable. In addition, data from the process can be used to predict the future performance of the process. If the chart indicates that the process being monitored is not in control, analysis of the chart can help determine the sources of variation, which can then be eliminated to bring the process back into control. A control chart is a specific kind of run chart that allows significant change to be differentiated from the natural variability of the process.

The control chart can be seen as part of an objective and disciplined approach that enables correct decisions regarding control of the process, including whether to change process control parameters. Process parameters should never be adjusted for a process that is in control, as this will result in degraded process performance.A process that is stable but operating outside of desired limits (e.g. scrap rates may be in statistical control but above desired limits) needs to be improved through a deliberate effort to understand the causes of current performance and fundamentally improve the process.

The control chart is one of the seven basic tools of quality control.

**Chart details:-**

A control chart consists of:

- Points representing a statistic (e.g., a mean, range, proportion) of measurements of a quality characteristic in samples taken from the process at different times [the data]
- The mean of this statistic using all the samples is calculated (e.g., the mean of the means, mean of the ranges, mean of the proportions)
- A center line is drawn at the value of the mean of the statistic
- The standard error (e.g., standard deviation/sqrt(n) for the mean) of the statistic is also calculated using all the samples
- Upper and lower control limits (sometimes called "natural process limits") that indicate the threshold at which the process output is considered statistically 'unlikely' are drawn typically at 3 standard errors from the center line

The chart may have other optional features, including:

- Upper and lower warning limits, drawn as separate lines, typically two standard errors above and below the center line
- Division into zones, with the addition of rules governing frequencies of observations in each zone
- Annotation with events of interest, as determined by the Quality Engineer in charge of the process's quality.

Graphs:- given below:-

Result :- conduct Shewart's experiments on known population.

**Experiment:-7**

**Object:-**Generation of random numbers for system simulation such as facility planning, job shop scheduling etc.

## Random Number Generation

Random numbers or Pseudo-random numbers are often required for simulations performed on parallel computers. The requirements for parallel random number generators are more stringent than those for sequential random number generators. As well as passing the usual sequential tests on each processor, a parallel random number generator must give different, independent sequences on each processor. We consider the requirements for a good parallel random number generator, and discuss generators for the uniform and normal distributions. These generators can give very fast vector or parallel implementations.

## Random Numbers and Simulation

In many fields of engineering and science, we use a computer to simulate natural phenomena rather than experiment with the real system. Examples of such computer experiments are simulation studies of physical processes like atomic collisions, simulation of queuing models in system engineering, sampling in applied statistics. Alternatively, we simulate a mathematical model, which cannot be treated by analytical methods. In all cases a simulation is a computer experiment to determine probabilities empirically. In these applications, random numbers are required to make things realistic.

Random number generation has also applications in cryptography, where the requirements on randomness may be even more stringent.

Hence, we need a good source of random numbers. Since the validity of a simulation will heavily depend on the quality of such a source, its choice or construction will be fundamental importance. Tests have shown that many so-called random functions supplied with programs and computers are far away from being random.

By generating random numbers, we understand producing a sequence of independent random numbers with a specified distribution. The fundamental problem is to generate random numbers with a uniform discrete distribution on {0,1,2,…,N} or more suitable on {0,1/N,2/N,…,1}, say. This is the distribution where each possible number is equally likely. For N large this distribution approximates the continuous uniform distribution U(0,1) on the unit interval. Other discrete and continuous distributions will be generated from transformations of the U(0,1) distribution.

At first, scientists who needed random numbers would generate them by performing random experiments like rolling dice or dealing out cards. Later tables of thousands of random digits created with special machines for mechanically generating random numbers or taken from large data sets as census reports were published.

With the introduction of computers, people began to search for efficient ways to obtain random numbers using arithmetic operations of a computer - an approach suggested by John von Neumann in the 1940's. Since the digital computer cannot generate random numbers, the idea is, for a given probability distribution, to develop an algorithm such that the numbers generated by this algorithm appear to be random with the specified distribution. Sequences generated in a deterministic way we call pseudo-random numbers. To simulate a discrete uniform distribution John von Neumann used the so-called middle square method, which is to take the square of the previous random number and to extract the middle digits.

**Example:** If we generate 4-digit numbers starting from 3567 we obtain 7234 as the next number since the square of 3567 equals 12**7234**89. Continuing in the same way the next number will be 3307.

Of course, the sequence of numbers generated by this algorithm is not random but it appears to be. However, as computations show the middle square method is a poor source of random numbers.

To summarize our discussion we need

- Precise mathematical formulations of the concept of randomness
- Detailed analysis of algorithms for generating pseudo-random numbers
- Empirical tests of random number generators

# What is a random sequence?

A sequence of real numbers between zero and one generated by a computer is called "pseudo-random" sequence if it behaves like a sequence of random numbers. So far this statement is satisfactory for practical purposes but what one needs is a quantitative definition of random behaviour.

In practice we need a list of mathematical properties characterizing random sequences and tests to see whether a sequence of pseudo-random numbers yields satisfactory results or not. Loosely speaking, basic requirements on random sequences are that their elements are uniformly distributed and uncorrelated. The tests we can perform will be of theoretical and/or empirical nature.

# Some definitions

D.H. Lehmer(1951) : "A random sequence is a vague notion embodying the idea of a sequence in which each term is unpredictable to the uninitiated and whose digits pass a certain number of tests, traditional with statisticians and depending somewhat on the uses to which the sequence is to be put."

J.N. Franklin (1962): " A sequence ($U_0$, $U_1$,…) (note: with $U_i$ taking values in the unit interval [0,1]) is random if it has every property that is shared by all infinite sequences of independent samples of random variables from the uniform distribution."

# Generating uniform random numbers

Deterministic generators yield numbers in a fixed sequence such that the forgoing k numbers determine the next number. Since the set of numbers used by a computer is finite, the sequence will become periodic after a certain number of iterations.

The general form of algorithms generating random numbers may be described by the following recursive procedure.

$X_n = f(X_{n-1}, X_{n-2}, ..., X_{n-k})$

with initial conditions $X_0, X_1, ..., X_{k-1}$. Here f is supposed to be a mapping from $\{0,1,...,m-1\}^k$ into $\{0,1,...,m-1\}$.

For most generators k=1 in which case the recursive relation simplifies to

$X_n = f(X_{n-1})$

with a single initial value $X_0$, the seed of the generator. Now f is a mapping from $\{0,1,...,m-1\}$ into itself.

In most cases the goal is to simulate the continuous uniform distribution U(0,1). Therefore the integers $X_n$ are rescaled to

$U_n = X_n/m$.

If m is large, the resulting granularity is negligible when simulating a continuous distribution.

**A good generator** should be of a long period and resulting subsequences of pseudo-random numbers should be uniform and uncorrelated. Finally, the algorithm should be efficient.

**Remark: You should note that initializing the generator with the same seed $X_0$ would give the same sequence of random numbers. Usually one uses the clock time to initialize the generator.**

Mathematicians have devised a variety of procedures to generate random numbers. With these procedures, random number generation can be done either manually or with the help of a computer. Also, several collections of random number tables are available. The most commonly used table contains uniformly distributed (or normally distributed) random numbers over the interval 0 to 1. To generate other types of random numbers which obey other distribution laws, we would require access to a computer.

The simplest method for obtaining random events is coin tossing. This method can be used to obtain an ideal random number generator. Here, we show that logistic map is able to simulate the coin tossing method. Also, we describe a numerical implementation of the ideal uniform random number generator. Comparing to usual congruential random number generators, which are periodic, the logistic generator is infinite, aperiodic and not correlated.

In modern science, random number generators have proven invaluable in simulating natural phenomena and in sampling data [1-2]. There are only a few methods for obtaining random numbers. For example, the simplest method is coin tossing, where the occurrence of heads or tails are random events. By virtue of the symmetry of the coin the events are equally probable. Hence they are called equally probable events. It is therefore considered that the probability of heads (tails) is equal to 1/2.

**Coin tossing** : The **coin tossing** belongs to the category of mechanical methods which includes also: dices, cards, roulettes, urns with balls and other gambling equipments. The mechanical methods are not frequently used in science because of the low generation speed. The methods characterized by high generation speed are those, which are based on intrinsic random physical processes such as the electronic and radioactive noise. Because the sequence of numbers generated with mechanical and physical methods are not reproducible, these methods have a great disadvantage in numerical simulations.

**Analytical methods:** Methods which are implemented in computer algorithms, eliminates the disadvantages of the manual and physical methods. These methods are characterized by high speed, low correlation of the numbers and reproducibility. The major drawback of these methods is the periodicity of the generated sequences.

**Middle square generators:** The middle square method was proposed by J. von Neumann in the 1940's. Therefore these generators are also called von Neumann generators in the literature. The middle square method consists of taking the square of the previous random number and to extract the middle digits. This method gives rather poor results since generally sequences tend to get into a short periodic orbit.

**Example:** If we generate 4-digit numbers starting from 3567 we obtain 7234 as the next number since the square of 3567 equals 12723489. Continuing in the same way the next number will be 3307. The resulting sequence enters already after 46 iterations a periodic orbit:

3567, 7234, 3307, 9362, 6470, 8609, 1148, 3179, 1060, 1236, 5276, 8361, 9063, 1379, 9016, 2882, 3059, 3574, 7734, 8147, 3736, 9576, 6997, 9580, 7764, 2796, 8176, 8469, 7239, 4031, 2489, 1951, 8064, 280, 784, 6146, 7733, 7992, 8720, 384, 1474, 1726, 9790, 8441, 2504, 2700, 2900, 4100, 8100, 6100, 2100, 4100

**Linear congruential generators:** The linear congruential generator (LCG) was proposed D.H. Lehmer in 1948. The form of the generator is $X_n = (aX_{n-1} + c) \bmod m$

| parameter | name | range |
|---|---|---|
| $m$ | the modulus | {1,2,...} |
| $a$ | the multiplier | {0,1,...,$m$-1} |
| $c$ | the increment | {0,1,...,$m$-1} |
| $X_0$ | the seed | {0,1,...,$m$-1} |

**The operation mod m is called reduction modulo m and is a basic operation of modular arithmetic. Any integer x may be represented as**
**$x = \text{floor}(x/m)\cdot m + x \bmod m$**
**where the floor function floor(t) is the greatest integer less than or equal to t. This equation may be taken as definition of the reduction modulo m.**
**If c = 0 the generator is called multiplicative. For nonzero c the generator is called mixed.**

**Monte Carlo Method of Simulation**

**The Monte Carlo method owes its development to the two mathematicians, John Von Neumann and Stanislaw Ulam, during World War II. The principle behind this method of simulation is representative of the given system under analysis by a system described by some known probability distribution and then drawing random samples for probability distribution by means of random number. In case it is not possible to describe a system in terms of standard probability distribution such as normal, Poisson, exponential, gamma, etc., an empirical probability distribution can be constructed.**

**The deterministic method of simulation cannot always be applied to complex real life situations due to inherently high cost and time values required so as to obtain any meaningful results from the simulated model. Since there are a large number of interactions between numerous variables, the system becomes too complicated to offer an effective simulation approach. In such cases where it is not feasible to use an expectation approach for simulating systems, Monte Carlo method of simulation is used.**

**It can be usefully applied in cases where the system to be simulated has a large number of elements that exhibit chance (probability) in their behaviour. As already mentioned, the various types of probability distributions are used to represent the uncertainty of real-life situations in the model. Simulation is normally undertaken only with the help of a very high-speed data processing machine such as computer. The user of simulation technique must always bear in mind that the actual frequency or probability would approximate the theoretical value of probability only when the number of trials are very large i.e. when the simulation is repeated a large no. of times. This can easily be achieved with the help of a computer by generating random numbers.**

**A random number table is presented here for the quick reference of the students.**

## *Random Number Table*

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 52 | 06 | 50 | 88 | 53 | 30 | 10 | 47 | 99 | 37 | 66 | 91 | 35 | 32 | 00 | 84 | 17 | 07 |
| 37 | 63 | 28 | 02 | 74 | 35 | 24 | 03 | 29 | 60 | 74 | 85 | 90 | 73 | 59 | 55 | 36 | 60 |
| 82 | 57 | 68 | 28 | 05 | 94 | 03 | 11 | 27 | 79 | 90 | 87 | 92 | 41 | 09 | 25 | 72 | 77 |
| 69 | 02 | 36 | 49 | 71 | 99 | 32 | 10 | 75 | 21 | 95 | 90 | 94 | 38 | 97 | 71 | 85 | 49 |
| 98 | 94 | 90 | 36 | 06 | 78 | 23 | 67 | 89 | 85 | 29 | 21 | 25 | 73 | 69 | 34 | 31 | 76 |
| 96 | 52 | 62 | 87 | 49 | 56 | 59 | 23 | 78 | 71 | 72 | 90 | 57 | 01 | 98 | 57 | 44 | 95 |
| 33 | 69 | 27 | 21 | 11 | 60 | 95 | 89 | 68 | 48 | 17 | 89 | 34 | 09 | 93 | 50 | 30 | 51 |
| 50 | 33 | 50 | 95 | 13 | 44 | 34 | 62 | 64 | 39 | 55 | 29 | 30 | 64 | 49 | 44 | 26 | 16 |
| 88 | 32 | 18 | 50 | 62 | 57 | 34 | 56 | 62 | 31 | 15 | 40 | 90 | 34 | 51 | 95 | 09 | 14 |
| 90 | 30 | 36 | 24 | 69 | 82 | 51 | 74 | 30 | 35 | 36 | 85 | 01 | 55 | 92 | 64 | 49 | 85 |
| 50 | 48 | 61 | 18 | 85 | 23 | 08 | 54 | 17 | 12 | 80 | 69 | 24 | 84 | 92 | 16 | 13 | 59 |
| 27 | 88 | 21 | 62 | 69 | 64 | 48 | 31 | 12 | 73 | 02 | 68 | 00 | 16 | 16 | 46 | 33 | 85 |
| 45 | 14 | 46 | 32 | 13 | 49 | 66 | 62 | 74 | 41 | 86 | 98 | 92 | 98 | 84 | 54 | 89 | 40 |
| 81 | 02 | 01 | 78 | 82 | 74 | 97 | 37 | 45 | 31 | 94 | 99 | 42 | 49 | 27 | 64 | 13 | 42 |
| 66 | 83 | 14 | 74 | 27 | 76 | 03 | 33 | 11 | 97 | 59 | 81 | 72 | 00 | 64 | 61 | 37 | 52 |
| 74 | 05 | 82 | 82 | 93 | 09 | 96 | 33 | 52 | 78 | 13 | 06 | 28 | 30 | 94 | 23 | 58 | 39 |
| 30 | 34 | 87 | 01 | 74 | 11 | 46 | 82 | 59 | 94 | 25 | 34 | 32 | 23 | 17 | 01 | | 73 |

**Following are the steps involved in Monte-Carlo simulation:-**

**Step I.**

**Obtain the frequency or probability of all the important variables from the historical sources.**

**Step II.**

**Convert the respective probabilities of the various variables into cumulative problems.**

**Step III.**

**Generate random numbers for each such variable.**

**Step IV.**
**Based on the cumulative probability distribution table obtained in Step II, obtain the interval (i.e.; the range) of the assigned random numbers.**
**Step V.**
**Simulate a series of experiments or trails.**
**Remarks. Which random number to use?**
**The selection of specific random number is determined by establishing a systematic and thorough selection strategy before examining the list of digits given in the random number table.**
**In general, the practical life situations or systems are simulated by building, first a basic inherent model & subsequently relaxing some or all of the assumptions so as to obtain a more precise model representation. Thus model building for simulations is a stepwise process and the final model emerges only after a large number of successive refinements.**
**Application of Monte-Carlo Simulation: Monte-Carlo simulation can now easily be applied to an example of the bread-seller. Let us suppose that the demands per unit of the bread along with their respective probabilities are as follows:**

| Days No. | Demand (per unit) | Probability |
|---|---|---|
| 1 | 20 | 0.10 |
| 2 | 21 | 0.15 |
| 3 | 22 | 0.25 |
| 4 | 23 | 0.20 |
| 5 | 24 | 0.10 |
| 6 | 25 | 0.05 |
| 7 | 26 | 0.15 |

**We can easily use a sequence of 2-digit random numbers of generating the demand based on the above information. By assigning two digit random numbers to each of the possible outcomes or daily demand, we have:**

| (Per unit) Days No. | Demand | Probability | Cumulative Probability | Random Nos. |
|---|---|---|---|---|
| 1 | 20 | 0.10 | 0.10 | 00 to 09 |
| 2 | 21 | 0.15 | 0.25 | 10 to 24 |
| 3 | 22 | 0.25 | 0.50 | 25 to 49 |
| 4 | 23 | 0.20 | 0.70 | 50 to 69 |
| 5 | 24 | 0.10 | 0.80 | 70 to 79 |
| 6 | 25 | 0.05 | 0.85 | 80 to 84 |
| 7 | 26 | 0.15 | 1.00 | 85 to 99 |

**The first entry in the random number table is 00 to 09. It means that there are 10 random numbers (00 to 09). Since each of the ten numbers has an even chance of appearing. The probability of each number = 1/10 or 0.10; a fact that is fully supported by the cumulative probability table.**
**Using the above procedure, by Monte Carlo method of simulation, demand for the required number of days can easily be determined using the random number table.**
**Now I'll take up few examples of random number to explain this & make its practical application clear.**
**Example 1**
**New Delhi Bakery House keeps stock of a popular brand of cake. Previous experience indicates the daily demand as given below:**

Consider the following sequence of random numbers: R. No. : 21, 27, 47, 54, 60, 39, 43, 91, 25, 20.

Using this sequence, simulate the demand for the next 10 days. Find out the stock situation if the owner of the bakery house decides to make 30 cakes every day. Also estimate the daily average demand for the cakes on the basis of simulated data.

**Table 1**

| Daily demand | Probability |
|---|---|
| 0 | 0.01 |
| 15 | 0.15 |
| 25 | 0.20 |
| 35 | 0.50 |
| 45 | 0.12 |
| 50 | 0.02 |

**Solution :**

**Table 2**

| Daily Demand | Probability | Cumulative probability | Random Nos. |
|---|---|---|---|
| 0 | 0.01 | 0.01 | 00 |
| 15 | 0.15 | 0.16 | 01 to 15 |
| 25 | 0.20 | 0.36 | 16 to 35 |
| 35 | 0.50 | 0.86 | 36 to 85 |
| 45 | 0.12 | 0.96 | 86 to 95 |
| 50 | 0.02 | 1.00 | 96 to 99 |

**Table 3**

| Demand | Random Numbers | Next demand | If he makes 30 cakes in a day | |
|---|---|---|---|---|
| | | | Left out | Shortage |
| 1 | 21 | 25 | 5 | |
| 2 | 27 | 25 | 10 | |
| 3 | 47 | 35 | 5 | |
| 4 | 54 | 35 | 0 | |
| 5 | 60 | 35 | | 5 |
| 6 | 39 | 35 | | 10 |
| 7 | 43 | 35 | | 15 |
| 8 | 91 | 45 | | 30 |
| 9 | 25 | 25 | | 25 |
| 10 | 20 | 25 | | 20 |
| Total | | 320 | | 10 |

Next demand is calculated on the basis of cumulative probability (e.g., random number 21 lies in the third item of cumulative probability, i.e., 0.36. Therefore, the next demand is 25. )

**Similarly, we can calculate the next demand for others.**

Total demand = 320

Average demand = Total demand / no. of days

The daily average demand for the cakes = 320 / 10 = 32 cakes.

**Summary**

**Hope you have understood the random number method of simulation. In next lesson we will study about the practical application of simulation.**

**RESULT:-** We have studied about Generation of random numbers for system simulation such as facility planning, job shop scheduling etc.