SVCE
Sri Venkateswara College of Engineering
Autonomous - Affiliated to Anna University

OE 18005

INDUSTRIAL ENGINEERING AND MANAGEMENT

OBJECTIVES :

- To know the basics Concepts of Industrial Engineering
- To understand about Work Study, Method Study and Time Study.
- To understand the concept of Motion Study.
- To recognize the need for Ergonomics and Ergonomics Model.

OUTCOMES :

1. Students will be able to distinguish the basics of Industrial engineering concepts.

2. Students will be able to apply work study and method study in Industrial case studies

3. Will be able to demonstrate the work sampling method and time study in a manufacturing process

4. Will be able to construct ergonomical models for industrial application.

5. Students will be able to examine the industrial process by applying different techniques

What is Industrial Engineering

- Electrical Engineering – to engineer an electrical product or system.
- Computer Engineering – to engineer a computer or a system of networked computers.
- Industrial Engineering?
  - To engineer an industry?? No.
  - To engineer an industrial product or system (efficiently and effectively): for manufactured goods or services,
  - To engineer a product or system for industry, the military, government, education, etc.
  - Efficiency and Quality Engineering!!

- Industrial engineering is the branch of engineering that involves figuring out how to make or do things better.
- Industrial engineers are concerned with
  - reducing production costs,
  - increasing efficiency,
  - improving the quality of products and services,
  - ensuring worker health and safety,
  - protecting the environment and complying with government regulations.

Definition of **Industrial Engineering**

- Industrial Engineering (IE) is concerned with the design, improvement and installation of integrated systems of people, materials, information, equipment and energy.
- It draws upon specialized knowledge and skill in the mathematical, physical and social sciences together with the principles and methods of engineering analysis and design to specify, predict and evaluate the results to be obtained from such systems

- **Improve process (way something is done)**

IEs made the lines at amusement parks more efficient so you can have fun!

Industrial Engineers . . . what they do

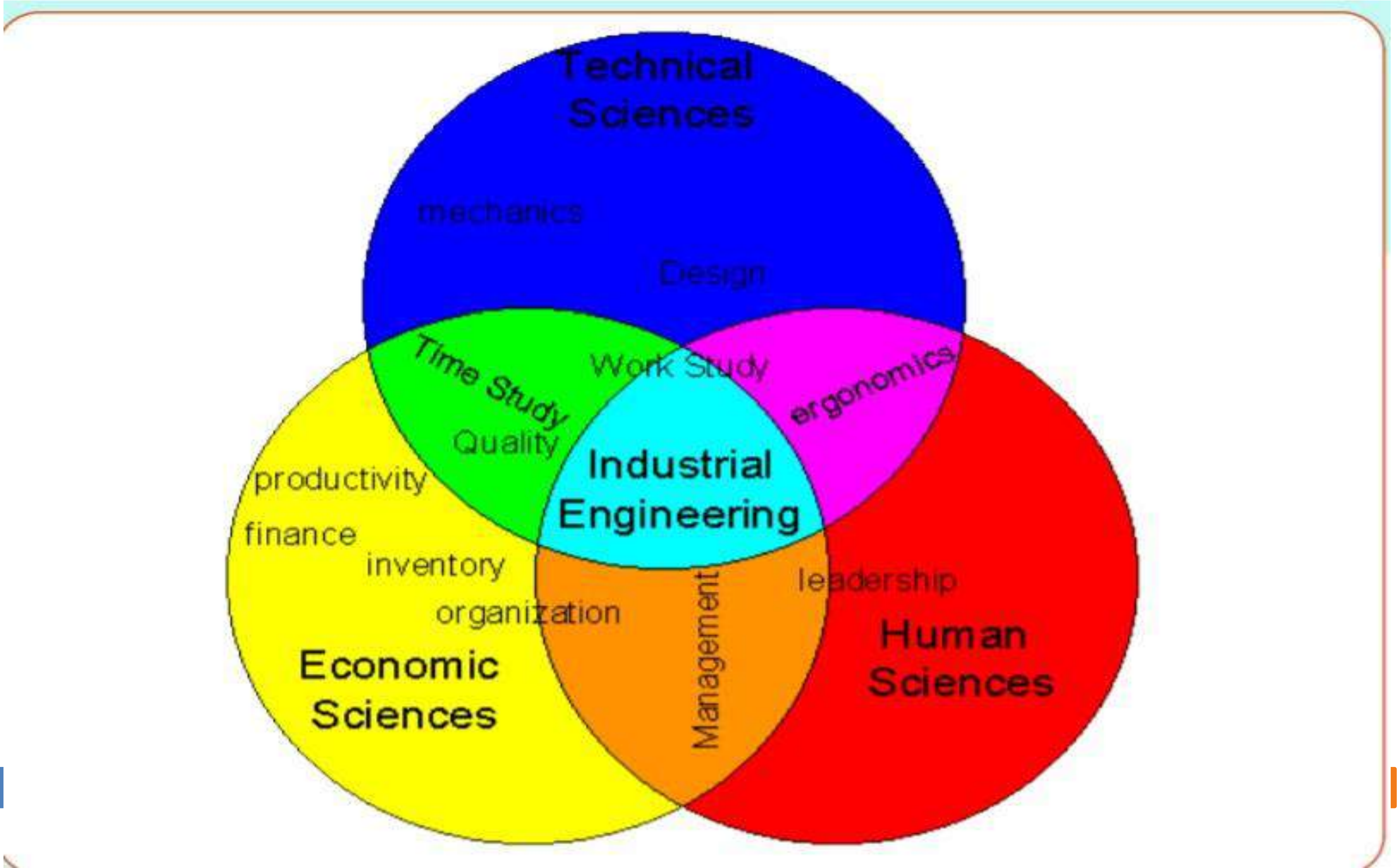
- Speed up delivery through “supply chain”

Industrial Engineers . . . what they do

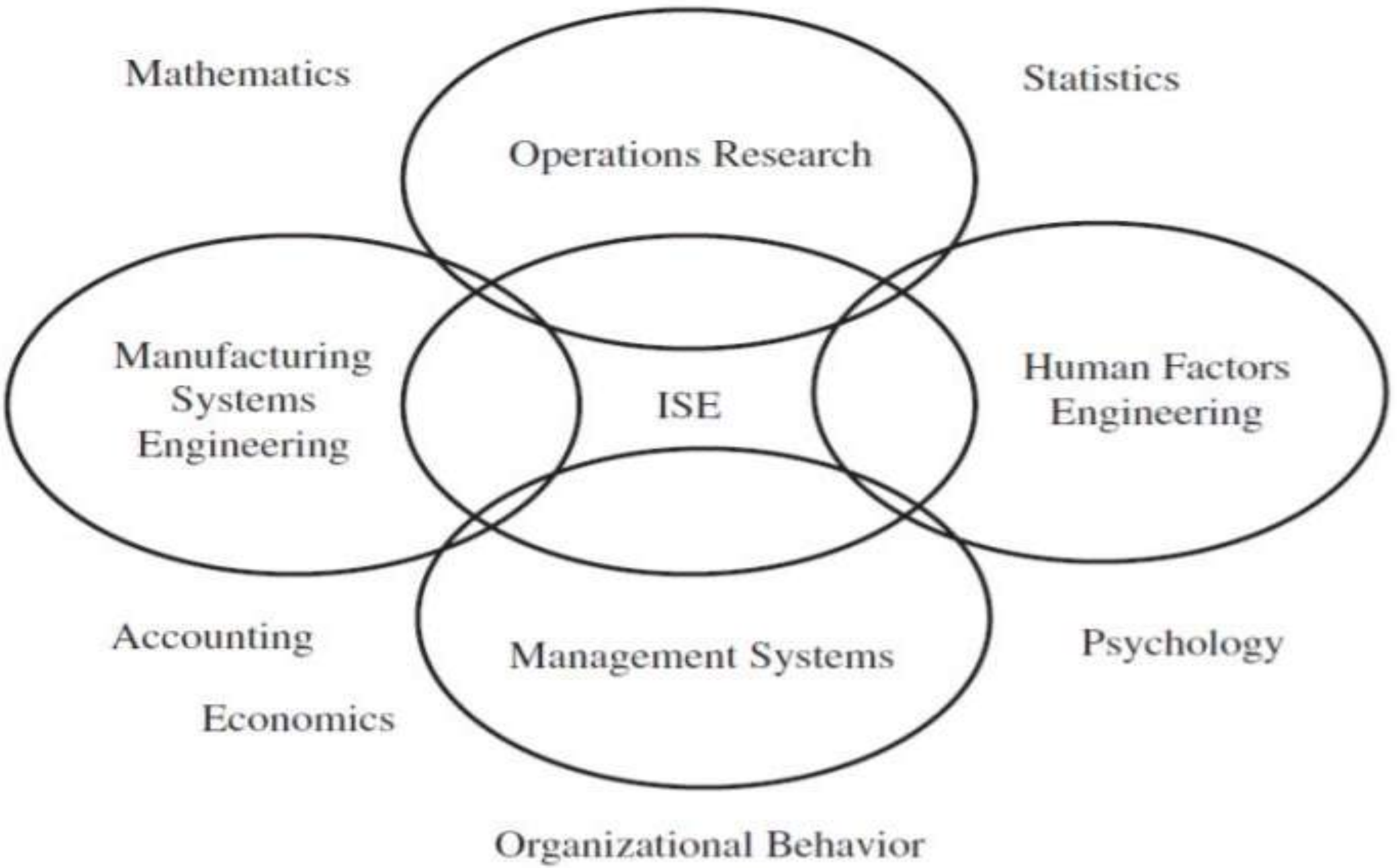
- Improve operations – safety and human factors

Example of better way to lift and move heavy items

DOMAIN OF IE


Technical Sciences
mechanics
Design
Time Study
Work Study
ergonomics
Quality
Industrial Engineering
productivity
finance
inventory
organization
leadership
Management
Economic Sciences
Human Sciences

SCIENCES OF IE



SCOPE

- Industrial engineers are expected to have employment growth of 14 percent over the projections decade, faster than the average for all occupations.
- As firms look for new ways to reduce costs and raise productivity, they increasingly will turn to industrial engineers to develop more efficient processes and reduce costs, delays, and waste.
- This focus should lead to job growth for these engineers, even in some manufacturing industries with declining employment overall.

SCOPE

- Industrial engineers have the opportunity to work in diverse fields, like, manufacturing, design, hardware, technology, retail, and even **healthcare**.
- Industrial Engineering provides a flexible field of study. It means you can have a customized approach to study – either on a technical or a management-oriented path.
- From delivery/logistics companies to eCommerce sites to manufacturing companies to textile industrial to F.M.C.G companies everyone needs them
- What comes into an organization (raw material, labour etc) to what stays in (inventory) and what goes out (finished goods) everything is controlled, managed and optimized by industrial engineers.

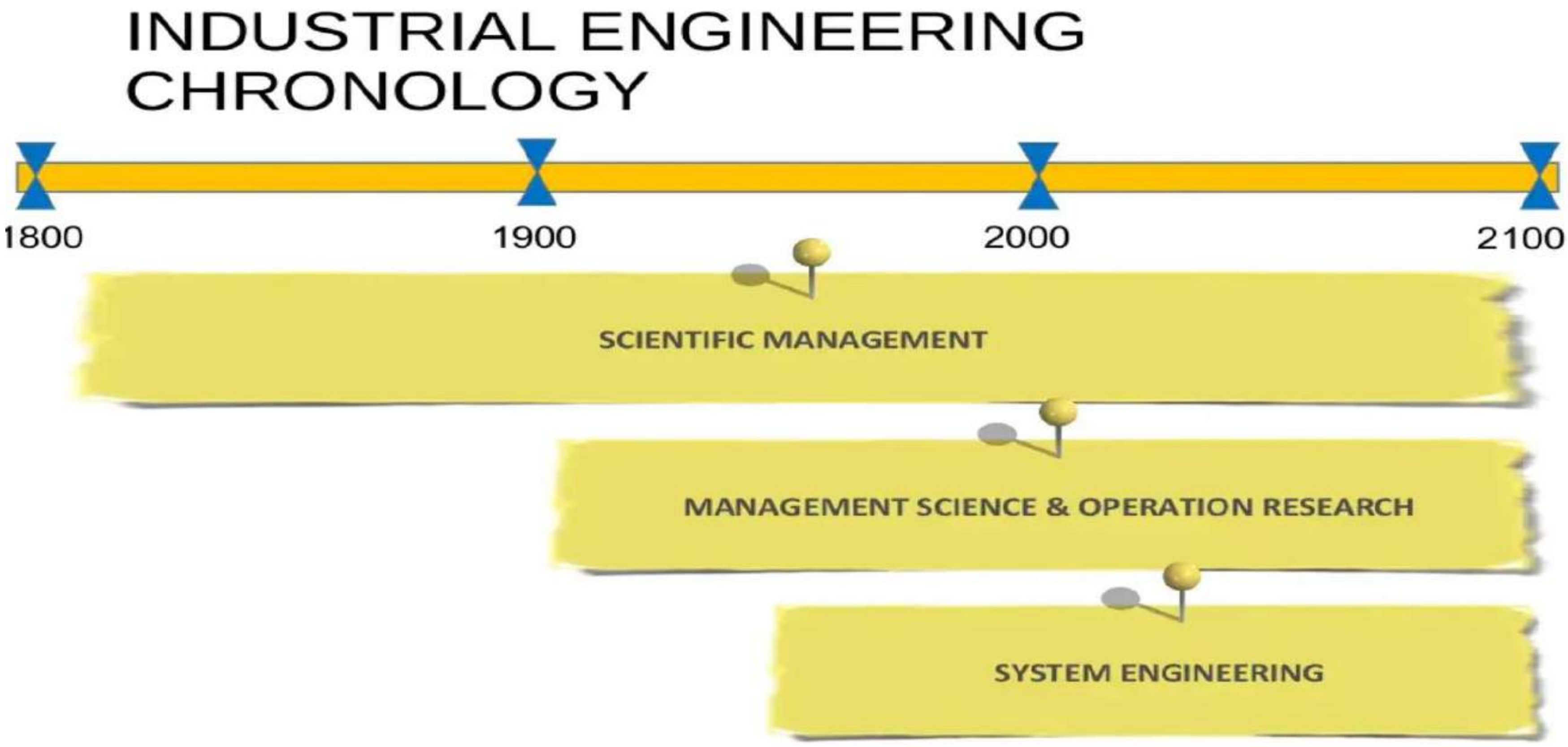
NEED FOR IE

- A diverse (various) discipline concerned with the design, improvement, installation, and management of integrated systems of people, materials, and equipment for all kinds of manufacturing and service operations.
- IE is concerned with performance measures and standards, research of new products and product applications, ways to improve use of scarce (limited) resources and many other problem solving adventures.
- An Industrial Engineer may be employed in almost any type of industry, business or institution, from retail establishments to manufacturing plants to government offices to hospitals.

What does an IE do?

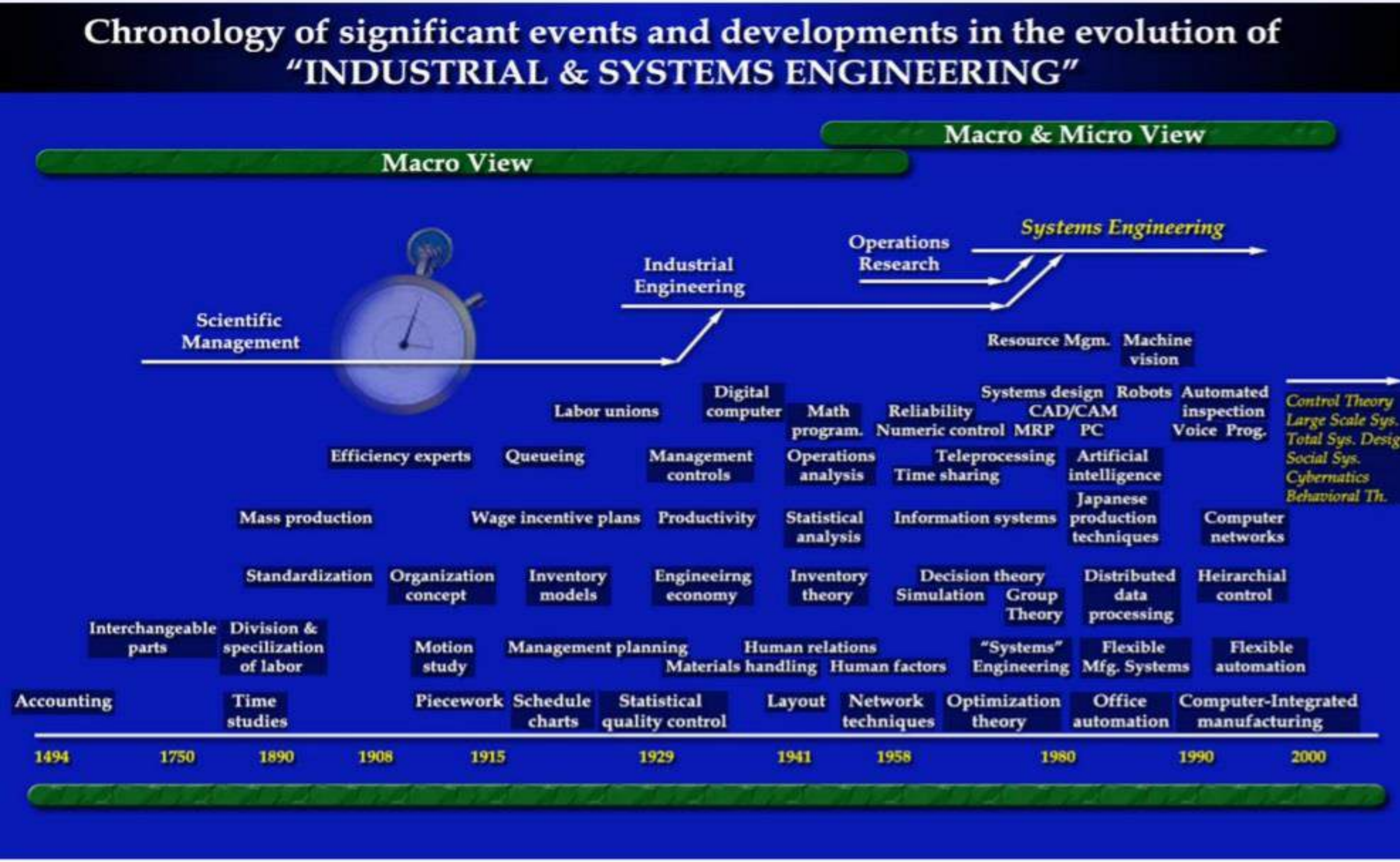
- Review production schedules, engineering specifications, process flows, and other information to understand manufacturing and service methods and activities
- Figure out how to manufacture parts or products or deliver services with maximum efficiency
- Develop management control systems to make financial planning and cost analysis more efficient
- Enact quality control procedures to resolve production problems or minimize costs
- Work with customers and management to develop standards for design and production
- Design control systems to coordinate activities and production planning to ensure that products meet quality standards

EVOLUTION


INDUSTRIAL ENGINEERING
CHRONOLOGY
1800
1900
2000
2100
SCIENTIFIC MANAGEMENT
MANAGEMENT SCIENCE & OPERATION RESEARCH
SYSTEM ENGINEERING

EVOLUTION

- The period from 1900 through the mid-1940s is generally referred as scientific management.
- Industrial engineering begins in the late 1950s and extends to the present time.
- Operations research had a great influence on IE practice starting in the mid 1970s and extend past mid-1990s.
- The fourth period known as industrial engineering and system engineering, is shown beginning around 2000 and extend indefinitely into the future.


Chronology of significant events and developments in the evolution of
"INDUSTRIAL & SYSTEMS ENGINEERING"
Macro & Micro View
Macro View
Systems Engineering
Operations Research
Industrial Engineering
Scientific Management
Resource Mgm.
Machine vision
Digital computer
Labor unions
Math program.
Reliability
Numeric control
Systems design
CAD/CAM
MRP
Robots
PC
Automated inspection
Voice Prog.
Control Theory
Large Scale Sys.
Total Sys. Design
Social Sys.
Cybernatics
Behavioral Th.
Efficiency experts
Queueing
Management controls
Operations analysis
Teleprocessing
Time sharing
Artificial intelligence
Mass production
Wage incentive plans
Productivity
Statistical analysis
Information systems
Japanese production techniques
Computer networks
Standardization
Organization concept
Inventory models
Engineeirng economy
Inventory theory
Decision theory
Simulation
Group Theory
Distributed data processing
Heirarchial control
Interchangeable parts
Division & specilization of labor
Motion study
Management planning
Human relations
Materials handling
Human factors
"Systems" Engineering
Flexible Mfg. Systems
Flexible automation
Accounting
Time studies
Piecework
Schedule charts
Statistical quality control
Layout
Network techniques
Optimization theory
Office automation
Computer-Integrated manufacturing
1494
1750
1890
1908
1915
1929
1941
1958
1980
1990
2000

HISTORY

History of Industrial Engineering

Charles W. Babbage, a mathematics professor	• *Book : The Economy of Machinery and Manufacturers* in 1832. • Developing **the learning curve**, **the division of task** and how learning is affected, and the effect of learning on the generation of waste.
Henry R. Towne and **Fredrick A. Halsey**	• Developing **wage incentive plans** to the ASME (American Society of Mechanical Engineers) increase the productivity of workers without negatively affecting the cost of production.
Fredrick Winslow Taylor	• The best known of **the pioneers in industrial engineering.** He was done potential improvements to be gained through analyzing the work content (minimum amount of work required to accomplish the task) of a job and designing the job for maximum efficiency.
Frank Bunker Gilbreth and his wife **Dr. Lillian M. Gilbreth**	• Worked on understanding **fatigue, skill development, motion studies**, as well as time studies.
Henry L. Gantt	• Developing cost, selection of workers, training, good incentive plans, and scheduling of work. He is the originator of **the Gantt chart**.

Impact of Related Developments – Impact of Operations Research

- The development of industrial engineering has been greatly influenced by the impact of an analysis approach called operations research.
- This approach originated in England and the United States during World War II and was aimed at solving difficult war-related problems through the use of science, mathematics, behavioral science, probability theory, and statistics.
- Following World War II, OR were extended to problems in industry and commerce.
- This resulted in considerable number of mathematicians and scientists who contributed to OR (and also IE).

Impact of Related Developments – Impact of Digital Computers

- Digital computers permit the rapid and accurate handling of huge quantities of data, so permitting the IE to design systems for effectively managing and controlling large, complex operations.
- The digital computer also permits the IE to construct computer SIMULATION models of manufacturing facilities in order to evaluate the effectiveness of alternative facility configurations.
- Computer-aided design (CAD) and computer-aided manufacturing (CAM).
- Generate process plans, bills of material, tool release orders, work schedules, operator instructions (ERP)

Impact of Related Developments – Service Industries

- HEALTHCARE- Cooperative programs in which group of hospitals share industrial engineering services. Use of Information Technologies and Optimisation techniques are helpful to achieve the expected services level in Healthcare Industries by optimum utilisation of resources.
- Government agencies - Thousands of Industrial Engineers are employed by government organizations to increase efficiency, reduce paperwork, design computerized management control systems, implement project management techniques, monitor the quality and reliability of vendor supplied purchases, and for many other functions.

PRODUCTIVITY

- Productivity is commonly defined as a ratio between the output volume and the volume of inputs.
- It measures how efficiently production inputs, such as labour and capital, are being used in an economy to produce a given level of output.
- Productivity is an indicator reflecting the changes in the performance of the enterprise and facilitates the management to control and plan its future operations of the enterprise

MEASURING PRODUCTIVITY

Material Productivity:

Material productivity = Output/Material input

Can be improved by

- Waste reduction and scrap control and
- Search for alternative cheaper materials
- Changes in product design
- Proper training and motivation of workers
- Better material planning and control

MEASURING PRODUCTIVITY

- **Labour Productivity:**

Labour productivity = Total revenue from production/expenditure on labour

Can be improved by:

- Providing training to workers to utilize best methods of production.
- Selection of product design and process of manufacture so as to ensure most economic use of labour.
- Improving working conditions in the plan

Measuring Productivity

- **Capital Productivity:**

Capital productivity = Turn over/Capital input

Can be improved by,

- By careful make or buy decisions.
- Better utilization of capital resources like land, building and machines.
- By adopting modern manufacturing techniques, like flexible manufacturing system, improved techniques of maintenance and proper plant layout etc.

Measuring Productivity

Machine Productivity

Machine Productivity = Output/Actual machine hours used

Can be increased by.

- Method study
- Preventive maintenance
- Utilization of proper machining parameters like speed, feed

Measuring Productivity

- **Energy Productivity:**

Energy Productivity = Output – Energy output

A general measure of productivity can be attained by following formula.

Productivity = output/Labour input + capital input + energy input + other inputs

EXAMPLE

A company is manufacturing 24,000 components per month by employing 100 workers in daily 8 hour shift. The company gets additional order to produce additional 6000 components. The management decides to employ additional workers. What will be production and productivity level when the number of additional employed workers are (i) 30, (ii) 25, and (iii) 20.

SOLUTION

Present productivity (of labour) = Total man hours (i.e. input) / Total man hours

= 24,000 components / (100 workers) (8 hours) (30 days of the month)

= 24000 / 24000 = 1 component/man hour

With increased order

(a) When additional 30 workers are hired

Production = 24,000 + 6000 = 30,000 components

Productivity (of labour) = Increased total production / Total man hours

= 30,000 / (100 + 30) (8) (30)

= 0.96 component/man hour

(b) When additional 25 workers are hired

Productivity = 1 component/man hour

(c) When additional 20 workers are hired

Productivity = 1.04 component/man hour

It is clear that production has increased 6000 units. Therefore.

Increase in production =(30,000 - 24,000 / 24,000) * 100 = 25 %

- It is observed that how the productivity is varying with the change of input labour while production target is kept constant.
- The labour productivity falls below the initial level of 1 component per man-hour if more than 25 workers are hired.
- Therefore, for constant production and working hours, you may conclude that not more than 25 workers should be hired for meeting this increase production requirement.

Example

Compute the productivity per machine hour with the following data. Also draw your interpretation.

Month	No. of Machines Employed	Working Hours	Machine Hours	Production Unit
March	400	225	90,000	99,000
April	500	200	100,000	100,000
May	600	250	150,000	135,000

We know P = Productivity per machine hour,

$$= \frac{\text{Production units}}{\text{Machine hours}}$$

For March $p = \frac{99,000}{90,000} = 1.1$

For April $p = \frac{100,000}{100,000} = 1$

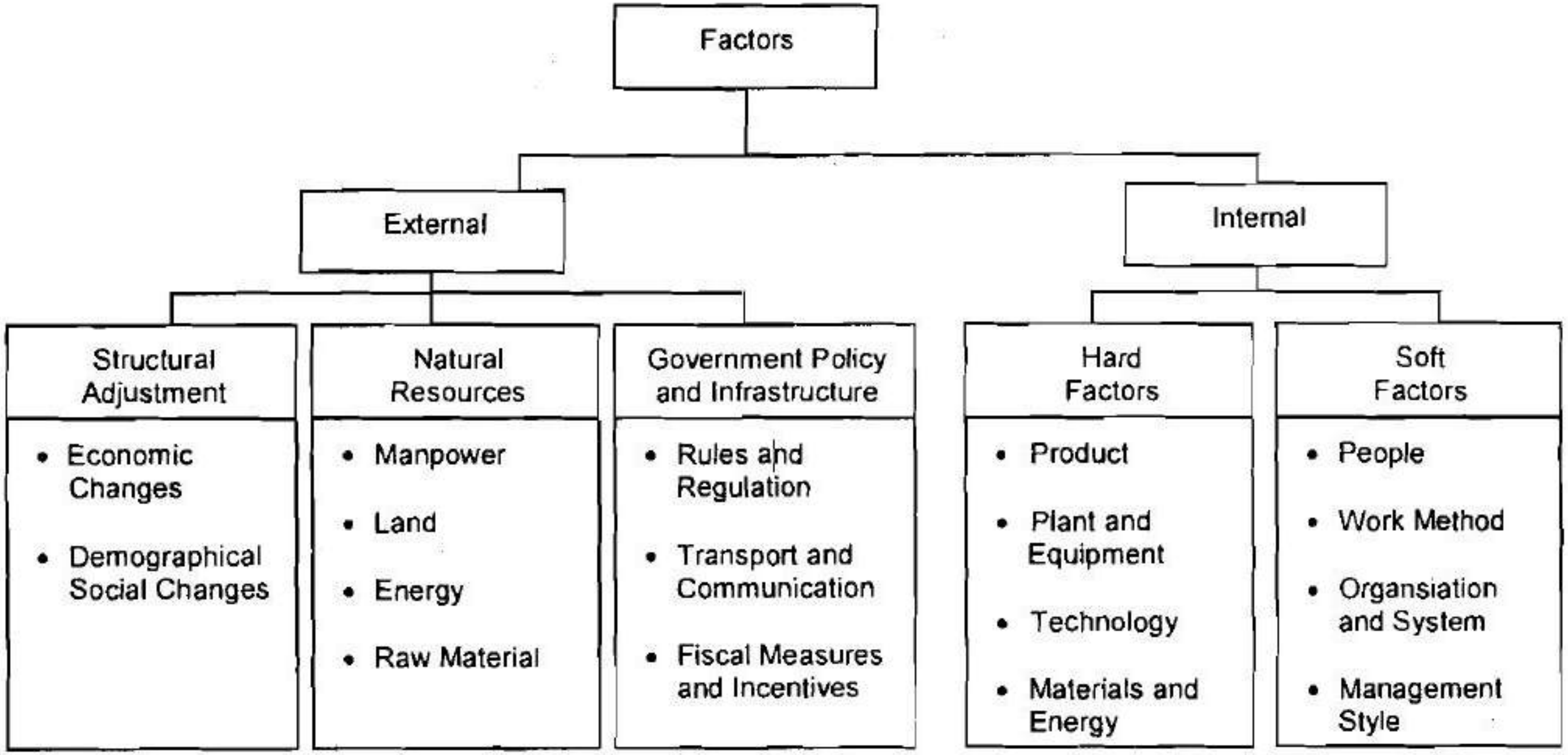
For May $p = \frac{135,000}{150,000} = 0.9$

Interpretation : Though the total production units are increasing, the productivity is declining.

FACTORS AFFECTING PRODUCTIVITY

a) External factors (non-controllable), and

(b) Internal factors (Controllable)



- Since some internal factors are more easily changed than others, it is useful to classify them into two groups : hard factors (not easily changed) and soft factors (easily changed).
- This classification helps to build priorities, which factors can easily be dealt with and which factors require stronger financial and organisational interventions.

Hard Factors

- *Product*- The extent to which the product meets customers requirement is meant by product factor productivity. 'Use value' is the amount that the customer is prepared to pay for a product of given quality. 'Use value' can be improved by better design and specification.
- *Plant and Equipment*- Once the product is designed, then next aspect which needs attention for productivity improvement is related to plant and equipment.

- *Technology* - Technological innovation constitutes an important source of achieving higher productivity. Increased volume of goods and services, quality improvement and new marketing methods, etc. can be achieved through increased automation and information technology.
- *Materials and Energy* - Even small efforts to reduce materials and energy consumption can bring remarkable results. These vital sources of productivity improvement include raw materials and indirect materials (process chemicals, lubricants, fuels, spare parts, engineering materials and packing materials, etc.).

Soft Factors

People –Each role has two aspects : application and effectiveness.

- Application is the degree to which people apply themselves to their work.
- People differ not only in their ability but also in their will to work.
- The ability to work can be improved by training and education.
- The will to work can be explained by a law of behavior : motivation decreases if it is either satisfied or blocked from satisfaction.

- *Work Method*- Improved work methods, especially in developing economics where capital is scare, technology intermediate and labour intensive methods dominant, constitute the most promising area for productivity improvement.

Work method techniques aim to make manual work more productive by improving the ways in which the work is done, the human movements are performed, the tools are used, the workplace is laid out, the material is handled and the machines are employed.

- *Organisation and Systems* – The organisation needs are to be dynamically operated and focused towards objectives and they must be maintained, serviced and reorganized from time to time to meet new objectives.

Dynamism and flexibility should be incorporated into the system design in order to maximise productivity. \

Rigidity is one reason for the low productivity in many organisations

- *Management Style* - Productivity experts believe that as much as 85 percent that can common problems are related to the quality and productivity problems that can be resolved by the management, not by the individual worker.

As there is no perfect management style, effectiveness depends upon when, where, how and to whom a manager applies a style.

Gains, in most of the organizations, are possible by effective use of resources under enterprise control by the management

EXTERNAL FACTORS

External factors include government policies and institutional mechanism, political, social and economic conditions, the business climate, the availability of power, workers, transport, finance, communication and raw materials. They affect individual enterprise productivity, but the organization concerned cannot actively control them.

Structural Adjustment

- Economic and demographic changes in the society often influence national and enterprise productivity independently of enterprise management. In the long term. however, this interaction is two-way

Economic Changes

- The most important economic changes are in employment patterns and in the composition of capital, technology, scale and competitiveness.

Demographical Social Changes

- Productivity and wages in the developing countries tend to be lower and the total cost of production is competitive. Two different and somewhat contradictory pressures influences productivity
- On the one hand, producers in developing countries must try to increase productivity to hold down production costs, on the other hand low wages of workers encourages to use more labour rather than investing heavily in capital and equipment

Natural Resources

Availability of natural resources is a major factor in facility location decision in any industry which affects productivity of the industry.

- ***Manpower*** -Several countries, which lack other natural resources have invested in human resource development for improving workers skills and changing their attitude through training, enhancing their education and motivating them by giving incentives and recognition.
- ***Land -*** For industrial expansion and intensive farming, land is an important natural resources.
- ***Energy-***The supply of energy influences capital and labour productivity. The high cost of energy and cut back on energy use decrease capital investment and encourage to increase the use of labour.
- ***Raw Materials*** The cost of minerals and other raw materials affects the economic rationale for repair, re-use and recycling

Government and Infrastructure

Government policies, strategies and programmes greatly affect productivity through :

- practices of government agencies,
- regulations such as price control, subsidies, etc.
- transport and communications,
- power, and
- fiscal measures and incentives like taxes and interest rate, etc

MEASURING PRODUCTIVITY

Productivity measurement system should provide a measureable index which can be used to achieve the goals of productivity in an organisation. Productivity measured is directly related to the productivity improvement programme. A good productivity measurement index should have the following characteristics.

- It should provide indices and information for comparison of performance in different periods.
- It should provide indices and information for comparison of performance with other similar organisastions/operations.
- It should provide the information on inter-relationship of different sub-systems. This information can be used in allocating the resources to improve the productivity of the whole system.

- It should incorporate both tangible and intangible outputs and inputs to the system.
- It should consider both tangible and intangible objectives in evaluation of productivity performance.
- The productivity measurement system should be hierarchical in nature, the productivity at lower levels give productivity of subsystem and productivity of sub-systems translate into overall productivity of the system.
- It should facilitate to devise a reward or an incentive scheme for workers.
- It should lead to the participation and involvement of employees of various levels.
- It should be economical and administratively easy to run the productivity measurement system.

An integrated productivity measurement system includes the productivity indicators for all the production and support departments. Some of the indicators that can be incorporated at shop/department level are as follows

Capital

- Output per machine hour,
- Machine down time, and
- Capacity utilization.

Material

- Kgs per unit output, and
- Equivalent rupees per unit output.

When to use productivity improvement programme

a) *Pressure for change:* Must be significant pressure for change both internally within the organization & also in its external environment.

(b) *Intervention at the top:* There must be managers or consultants at or near the top who are committed and who provide leadership in programme design and implementation.

(c) *Diagnosis and participation:* Active participation at several management levels in diagnosis of problem areas & improvement planning.

(d) *Invention of new solutions:* The invention and development of new ideas, methods and solutions to problems must be encouraged.

(e) *Experimentation with new solutions:* Willingness and permission from the top to take risks and experiment with new solutions in search for results.

(f) *Reinforcement from positive results:* There must be monitoring, review and positive reinforcement over a long-term period in order to make short-term improvements permanent

Main elements of productivity improvement programmes.

- There should be free-flow communication between different structural elements of the organisation.
- Top management must be wholly committed to the programme
- Full awareness and understanding of the programme objectives must exist at all organisational levels. Good labour-management relations are vital.

- Recognition of the key role played by workers is crucial and must be demonstrated through a sound productivity gains-sharing system.
- The productivity improvement techniques (technical, behavioural and managerial) chosen for the programme have to fit the situation and needs.
- Monitoring, evaluation and feedback processes to identify results and barriers provide a basis for design improvements.

STEPS FOR ‘PIP’

Step 1: Identify areas that are “ripe” for productivity improvement.

Step 2: Locate models in other jurisdictions.

Step 3: Define the roles of those who will be involved in planning and implementing the program.

Step 4: Set realistic goals and objectives.

Step 5: Choose among alternatives.

Step 6: Anticipate problems.

Step 7: Implement the program.

Step 8: Evaluate the program.

WAGES AND INCENTIVES

- A wage is monetary compensation (or remuneration, personnel expenses, labour) paid by an employer to an employee in exchange for work done.
- Payment may be calculated as a fixed amount for each task completed (a task wage or piece rate), or at an hourly or daily rate (wage labour), or based on an easily measured quantity of work done
- A wage may be defined as the sum of money paid under contract by an employer to worker for services rendered.

Objectives of Wage- Incentive Schemes

(i) As a useful tool for securing a better utilization of manpower, better productivity scheduling and performance control, and a more effective personnel policy.

ii) To improve the profit of a firm through a reduction in the unit costs of labor and materials or both.

(iii) To increase a worker's earning without dragging the firm into a higher wage rate structure regardless of productivity.

(iv) To avoid additional capital investment for the expansions of production capacity.

FACTORS AFFECTING

Demand and Supply of Labour:

- If the number of workers required is more than availability of workers, then employees will be paid higher rate of work and vice versa.

Legal Provisions:

- The government had made cretin laws/acts for fixation of minimum wages to the workers such as minimum wages act 1948. According to this act, the employer must pay minimum wages to the worker

Ability to Pay:

- A company running into losses will not be in a position to pay more than minimum wages, whereas a profit making company can give workers a share in the profit.

Nature of Job:

- Depends upon the worker’s skill and the conditions of work. Some jobs can be done by skilled employees while some jobs can be done by unskilled employees. Wages can be high or low, depending upon the worker’s skill and conditions of work.

Working Hours:

- Wages also depends upon the number of hours worked per day and the number of holidays.

Comparative Wage Levels:

- Wage rates also depend upon the wages paid in competitive firms for the same type of work. Wages are therefore fixed after conducting wage surveys.

Cost of Living:

- Cost of living also determines the wage rates. Wages should be such which satisfies the minimum needs of workers.

Type of Employment:

- Wages depends upon the type of employment i.e. regular employment or contractual employment. A regular and permanent job provides security of service

Methods of Wage Payment

1. Time Wage System -In this method worker is paid for the amount of time he has spent on the job. The period of time may be an hour, a day, a week, a month and the wages depend upon the period of time.

Wages are paid for the amount of time spent not on the basis of output. Thus, it is a non- variable method of wage payment.

Wages= number of hours worked* rate per hour

APPLICABILITY :

- This method is used when it is difficult to fix standard time for the job and machines used are costly
- When production process is complicated and requires high degree of skill.

ADVANTAGES

- Very simple as it is easy to calculate the time spent on the job.
- When the quality of the product is more important

DISADVANTAGES

- Under this method the workers slows down their work as there is no pressure of making required amount of pieces.
- Requires a lot of supervision to ensure better productivity

2. Piece Rate System:

- Piece rate system is a system in which wages are paid in accordance with the number of units of work produced.
- This is independent of time spent on the job.
- A fixed rate of wage is paid for each piece of unit produced.

For Example: If a worker produces 100 pieces per day and he is paid at the rate of Rs.1.2 per piece, the daily wage is 100 x 1.2 = Rs.120

Advantages:

- This system is simple in working and the workers can easily calculate their wages.
- This system helps in distinguishing efficient and inefficient workers.
- Strict supervision is not required in this system.

Disadvantages:

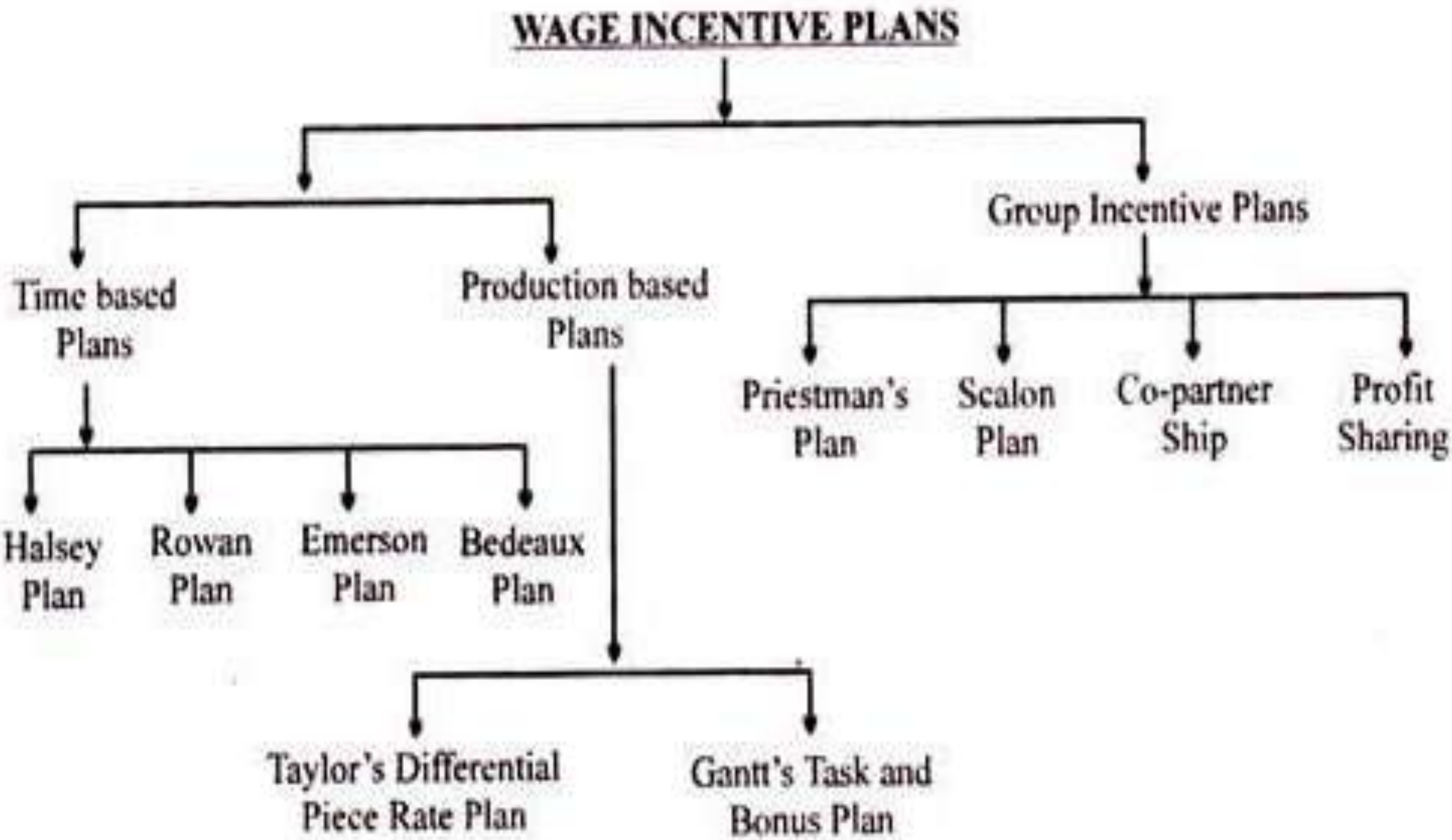
- This system does not guarantee a fixed minimum wage to a worker.
- The quality of goods will be poor as workers try to speed up their work in order to produce more.
- There will be increase in wastage of materials.

Wage Incentive

- Wage incentive refers to performance linked compensation paid to improve motivation and productivity. It is the monetary inducements offered to employees to make them perform beyond the acceptance standards.
- Incentive pay is the payment that is tied to the achievement of specific objectives that have been pre-determined and communicated to the employees that are on the plan.
- Incentives are provided as a motivation to the workforce to complete more tasks and build loyalty to the organization

Difference in Wage Incentive and Bonus

- A bonus is the decision to pay one, a group or all employees, based on criteria decided by management to reward past achievements, such as reaching a specific profit or target, or some important milestones for the organization.
- Incentive pay is the payment that is tied to the achievement of specific objectives that have been pre-determined and communicated to the employees that are on the plan


WAGE INCENTIVE PLANS
Group Incentive Plans
Time based Plans
Production based Plans
Priestman's Plan
Scalon Plan
Co-partner Ship
Profit Sharing
Halsey Plan
Rowan Plan
Emerson Plan
Bedeaux Plan
Taylor's Differential Piece Rate Plan
Gantt's Task and Bonus Plan

Halsey Plan

Under this plan a standard time is fixed for completing a work in advance. A worker completing his task in less than the standard time is paid for some of the time saved. The payments for time saved vary from 33 ⅓% to 66⅔% but generally wages for one half of time saved are paid. The wage of a worker is given by

$$W = T \times R + (S - T/2)\, R$$

S= Standard time or allowed time to complete the job.

T = Time taken

R = Hourly wage rate

ADVANTAGES

- It guarantees minimum wages to all workers, whether efficient or inefficient.
- Efficient workers are induced to show better results by offering them additional wages as incentive.

LIMITATIONS

- The quality of products suffers because workers try to complete the work in shortest possible time.
- Workers get only a percentage of return on their over-achievement

ROWAN PLAN

- A worker is guaranteed minimum wages for time spent on the job.
- He gets bonus for completing the job in less than the standard time.
- The only difference between Halsey and Rowan Plans is the method of calculating bonus is that proportion of the wages of the time taken which he saved bears to the standard time allowed.

$$W = T \times R + (S\text{-}T/S) \times T \times R$$

EXAMPLE

Standard Time: 32 hours

Actual Time taken: 26 hours

Hourly Rate: 4

Solution:

$$26 \times 4 + (32-26) = 104 + 6/32 \times 26 \times 4$$

$$= 104 + 19.50 = \text{Rs. } 123.50$$

The additional bonus, a worker will get is Rs. 19.50 in this case. However, the total saving of 6 hours amounts to Rs. 24 so Rs. 4.50 goes to management and Rs. 19.50 to worker.

Advantages of Rowan Plan:

1. This method provides minimum wages to workers.
2. Labour cost per unit is reduced because time saved is shared by the worker and management both.

Disadvantages of Rowan Plan:

1. The calculation of bonus under this system is complicated. In Halsey plan workers know that he will get additional wages for half of the time saved. In this method a certain proportion of time saved is paid as incentive.
2. This method is unjust for efficient workers since bonus is paid at decreasing rate.

Emerson Plan

- A standard output is fixed for determining the efficiency of workers.
- A worker reaching up to 66⅔% of efficiency is paid only minimum wages and bonus is paid only when his efficiency crosses this limit.
- The rate or bonus increases with the increase in efficiency.
- Under this plan bonus is 20% of wages earned at 100% efficiency and increases by 1% with every percent increase in efficiency.
- If efficiency is 110% then bonus will be 30% at this level.
- Efficiency of workers is well acknowledged in this system.

- For example, if standard time for a job is 6 hours and hourly rate is Rs.3.
- If a worker completes a job in 6 hours, the efficiency of worker is 100%.
- His wages will be 6 x 3 + bonus @20% i.e. Rs.18 + 20% of 18 = Rs.21.6

Benefits of Emerson Plan:

1. It is simple easily understandable by workers.
2. Workers get security because minimum wages are paid if efficiency is up to 66⅔% .

Limitations of Emerson Plan:

1. Standards may be set fairly high and workers may not be able to achieve them.
2. Workers may not be encouraged to increase their output beyond the standard level because benefits may be nominal after that level.

Bedeaux Plan

- It provides comparable standards for all workers.
- The benefit of time saved goes both to the worker and his supervisor in the ratio of 3/4 and 1/4th respectively.
- A supervisor also helps a worker in saving his time so he is also given some benefit in this method.
- The standard time for each job is determined in terms of minutes which are called Bedeaux points or B's.
- Each B represents one minute through time and motion study.
- A worker is paid time wages up-to standard B's or 100% performance.
- Bonus is paid when actual performance exceeds standard performance in tenns of B's.

W=TxR+75% (S-T)R

where, w= Total wages

S=Standard time

T=Time taken to complete the job

R=Rate;

For example, if standard time for a job is 6 hours i.e 360 B’s and wage rate is Rs.3 per hour. If a worker completes his job in 5 hours i.e 300 B’s, he saves 60B’s.

His total wages will be:

W=5×3+75 %(6-5)x3

=15+75%of 3=**Rs.17.25**

Advantages of Bedeaux Plan:

1. It ensures minimum wages to all workers.

2. The supervisor is motivated to co-operate with the workers for increasing their efficiency.

Limitations of Bedeaux Plan:

1. Workers are tempted to hurry up with the job and strict supervision will be necessary for maintaining proper quality control.

2. Workers resent sharing of their efforts with supervisors or superior.

PRODUCTION BASED PLANS

(i) Taylor's Differential Piece-Rate Plan:

- The underlying principle of this system is to reward an efficient worker and penalise the inefficient person. In Taylor's system, inefficient persons have no place in his organization.
- The standard time was fixed for completing a task with the help of time and motion study. If a worker completes the task in the standard time he is paid at higher rate and lower rate is paid if more than the standard time is taken.

The main features of this system

1. Minimum wages are not guaranteed in this plan.

2. A standard time fixed for taking and completing the task.

3. Different rates are fixed for taking standard time or more.

4. Higher rate is given if work is completed in standard or less time and lower rate is offered if more than standard time is taken.

The main characteristics of this system are that two rates of wage- one lower and one higher are fixed.

EXAMPLE

- A standard output of 200 units is fixed in an 8 hours' time. A rate of 45P is paid if the output is 200 or more units and 35P, if production is less than 200 units.
- Worker A has produced 240 units and B produced 180 units. The wages to be paid to worker A will be Rs. 108 i.e. (240 x 0.45) and that to B will be Rs. 63 i.e. (180 x 0.35).

(ii)Gantt's Task and Bonus Plan:

- This method is named after H. L. Gantt, a close associate of F.W.T. Taylor and tried to improve Taylor's method of wage payment.
- The workers are guaranteed minimum wages for taking standard time or more.
- A person taking less than the standard time gets time wages plus bonus.
- The main feature of this plan is that it combines time rate, piece rate and bonus. A standard time is fixed for doing a particular job.
- Worker's actual performance is compared with the standard time and his efficiency is determined.

The characteristics of this scheme are as follows:

1. A standard time is fixed for completing the work, and
2. A worker taking standard or more time gets wages on hourly rate.
3. A bonus ranging from 25% to 50% is paid for completing the task in less than standard time.

If a worker completes the job within standard time (100% efficiency), he is given wages for the standard time and bonus of 20% of wages earned.

If the worker completes the job in less than the standard time (i.e. efficiency more than 100%), wages are paid according to piece rate.

Example

- A standard time of 10 hours is allowed to complete a task and hourly rate is Rs. 5.
- A person completing the task in 10 hours will get Rs. 50 as wages. If the same task is completed in 8 hours then wages will be Rs. 12: Rs. 8 will be for time spent and Rs. 4 for bonus (taking 50% as the rate of bonus).

GROUP INCENTIVE PLAN

Priest-man's Plan:

- A standard production is fixed for the whole enterprise under this plan.
- If productivity exceeds the standard then bonus is paid in accordance with the increase. In case production does not reach the standard then workers get maximum wages only.
- For example, a standard production of 200,000 units is fixed for the year.Actual production during the year is 240,000 units since production has gone up by 20% workers will get 20% higher wages as bonus

GROUP INCENTIVE PLAN

Scalon Plan:

- There is a payment of one percent participating bonus for every one percent increase in productivity under this plan. The bonus is available to all workers except top management.
- The entire amount of bonus is not paid every month. A reserve fund of one-half of first fifteen percent is created for off-setting any change in labour cost.
- In case, this reserve remains unused at the end of the year then this amount is also distributed among workers in the last month of the year and a fresh reserve is created in the year.

Co-Partnership:

- The employees are offered shares of the enterprise at reduced rates in this plan.
- The payment is also collected in instalments and employees share profits of the enterprise as its members.
- The underlying idea of this method is to make workers feel as a part of the organization and understand view point of the management.

Profit Sharing:

- When shareholders share profits for contributing towards capital then workers should also get a part of profits for contributing their labour.
- The workers are an integral part of any organization and their contribution to its prosperity should also be rewarded by making them the recipients of profits.
- This realisation that employees/workers contribute significantly to increase profit has encouraged the adoption of this system.

Benefits of Group Incentive Plans

(1) Easy to implement:

It is easy to implement since measurement of group output is easy than the individual's output.

(2) Low Overhead Cost:

The overhead cost is reduced because of reduced paper work. In general, individual incentive plans tend to motivate the workers to a larger extent than group incentive plans. With the increased rate of production the unit production cost is reduced.

Limitations of Group Incentive Plans:

(i) Tend to lower the overall productivity.

(ii) Due to uniformity of pay irrespective of individual's lower or higher contribution in a group effort personnel problem arise

SVCE
Sri Venkateswara College of Engineering
Autonomous - Affiliated to Anna University

OE 18005

INDUSTRIAL ENGINEERING AND MANAGEMENT

OBJECTIVES :

- To know the basics Concepts of Industrial Engineering
- To understand about Work Study, Method Study and Time Study.
- To understand the concept of Motion Study.
- To recognize the need for Ergonomics and Ergonomics Model.

OUTCOMES :

1. Students will be able to distinguish the basics of Industrial engineering concepts.

2. Students will be able to apply work study and method study in Industrial case studies

3. Will be able to demonstrate the work sampling method and time study in a manufacturing process

4. Will be able to construct ergonomical models for industrial application.

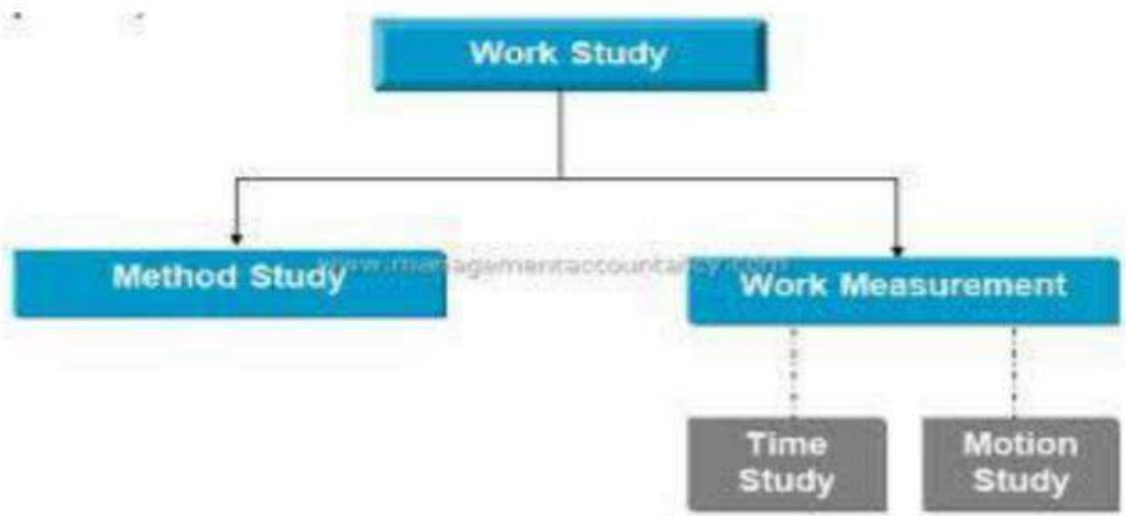
5. Students will be able to examine the industrial process by applying different techniques

UNIT II WORK STUDY, METHOD STUDY & MICRO AND MEMO MOTION STUDY

Definition, objective and scope of work study. Human factors in work study. Work study and management, work study and supervision, work study and worker. Method study Definition, objective & scope, activity recording and exam aids. Charts to record moments in shop operation process charts, flow process charts, travel chart and multiple activity charts. (With simple problems). Charts to record moment at work place principles of motion economy, classification of moments two handed process chart, SIMO chart, and micro motion study. Development, definition and installation of the improved method, brief concept about synthetic motion studies.

WORK STUDY

- The systematic examination of the method of carrying on activities so as to improve the effective use of resources and to set up standards of performance for the activities being carried out.



- It is a generic term for those techniques, method study and work measurement which are used in the examination of human work in all its context. And which lead systematically to the investigation of all the factors which affect the efficiency and economy of the situation being reviewed, in order to effect improvement

OR

- It is that body of knowledge concerned with the analysis of the work methods and the equipment used in performing a job, the design of an optimum work method and the standardization of proposed work methods.

Work Study

- Work study has contributed immeasurably to the search for better method, and the effective utilization of this management tool has helped in the accomplishment of higher productivity.
- Work study is a management tool to achieve higher productivity in any organization whether manufacturing tangible products or offering services to its customers.

Method study

- It is the systematic recording & critical examination of existing and proposed ways of doing work, as a means of developing and applying easier and more effective methods and reducing cost

Work measurement / Time study

- It is the application of techniques designed to establish the time for a qualified worker to carry out a specified job at a defined level of performance

Objectives of Work Study

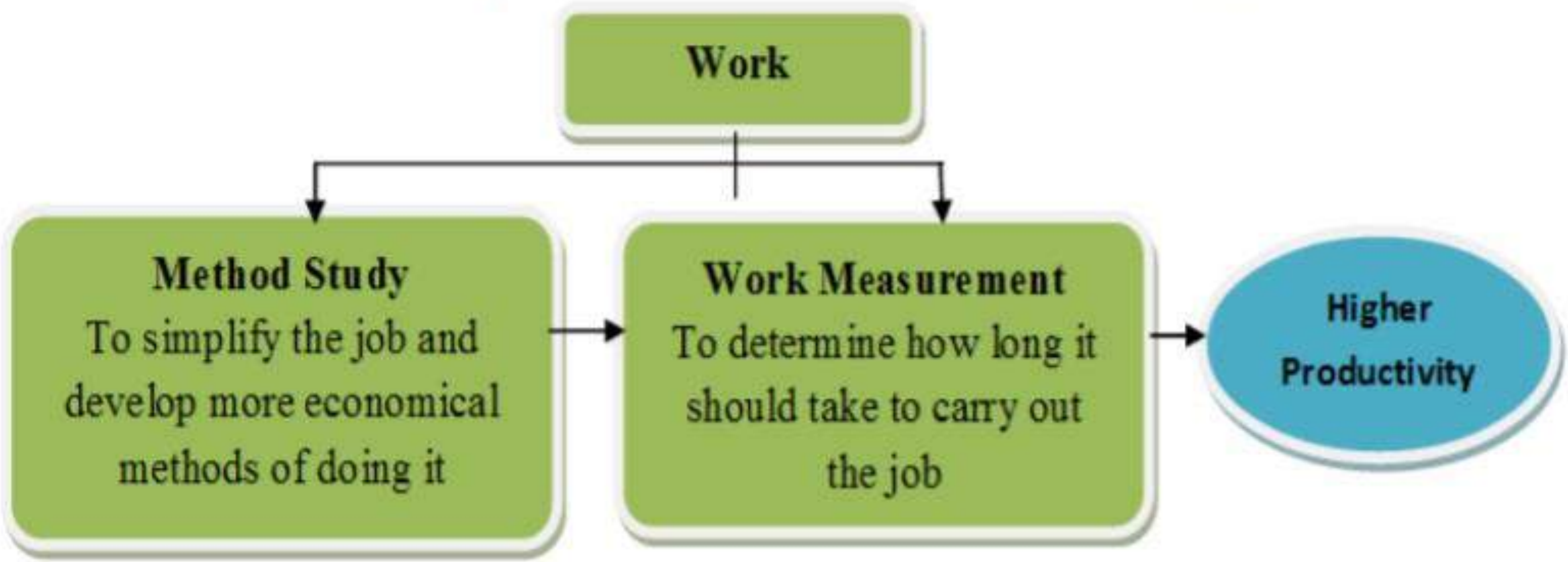
- To analyze the present method of doing a job, systematically in order to develop a new and better method
- To measure the work content of a job by measuring the time required to do the job for a qualified worker and hence to establish standard time.
- To increase the productivity by ensuring the best possible use of human, machine and material resources and to achieve best quality product/ service at minimum possible cost
- To improve operational efficiency

BENEFITS OF WORK STUDY

- Increased productivity and operational efficiency
- Reduced manufacturing costs
- Improved work place layout
- Better manpower planning and capacity planning
- Fair wages to employees
- Better working conditions to employees
- Improved work flow
- Reduced material handling costs

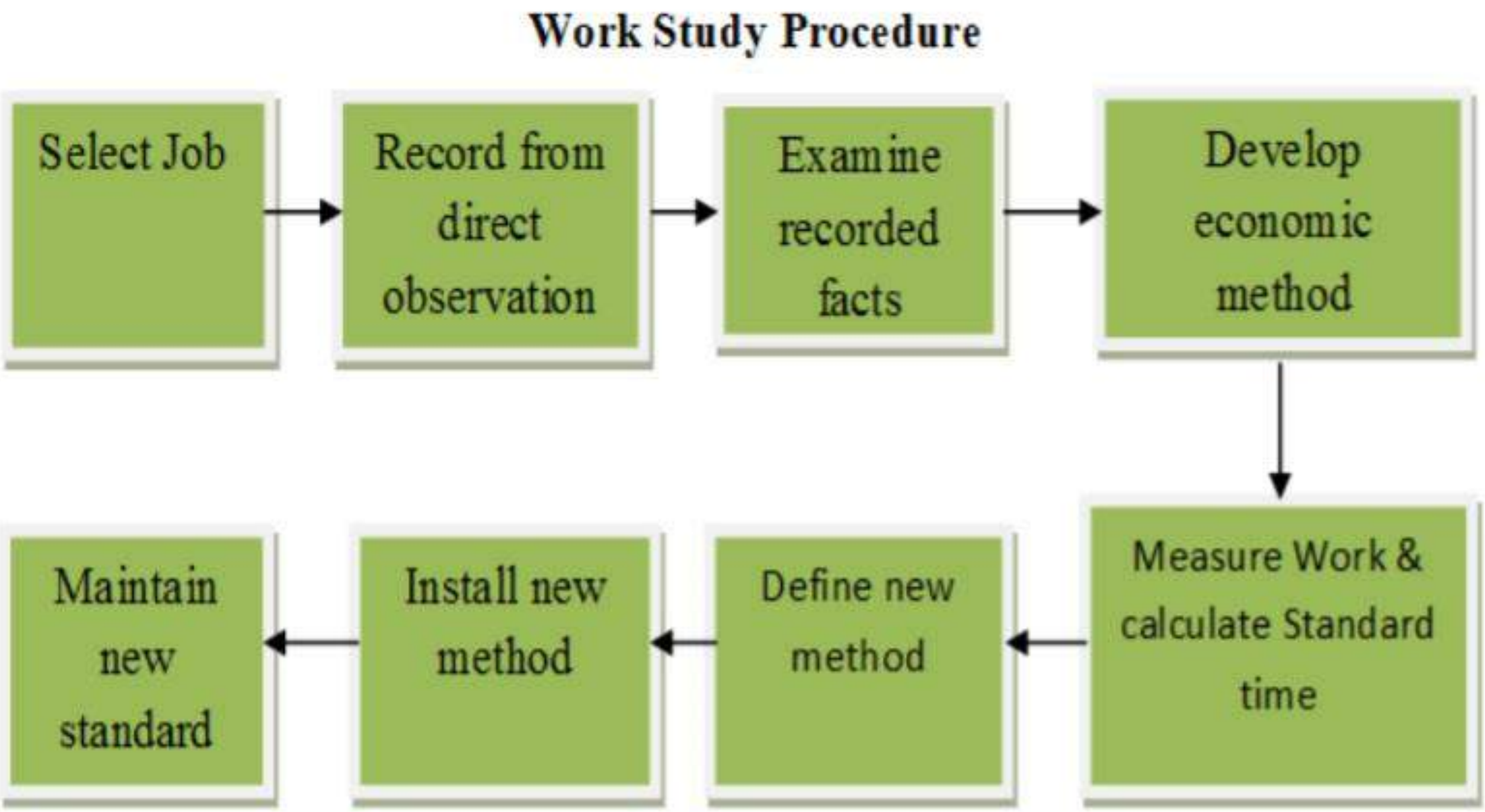
SCOPE OF WORK STUDY

Relationship between Method Study and Work Study



Source: ILO, Introduction to Work Study, *Universal Publishing Corporation, India 1986, PP.34.*

- Method study and work measurement are closely linked to each other as both are associated with work study.
- Method study reduces the content of job and work measurement investigates and reduces ineffective time associated with job with establishment of standard time.
- This results into efficient working operations leading to increase in productivity of that process


Work Study Procedure
Select Job
Record from direct observation
Examine recorded facts
Develop economic method
Measure Work & calculate Standard time
Define new method
Install new method
Maintain new standard

METHOD STUDY

- Systematic recording and critical examination of existing and proposed ways of doing work, as a means of developing and applying easier and more effective methods and reducing cost
- Work methods analysis or method study is a scientific technique of observing , recording and critically examining the present method of performing a task or operation with the aim of improving the present method and developing a new and cheaper method.
- It is also known as method improvement or work improvement.

- Its aim is to find best possible manufacturing procedure that requires least time and less fatigue to worker.

Used to analyze

- Movement of body, people, or material
- Activities of people & machines

Method study is a technique to reduce the work content mainly by eliminating unnecessary movements by workers, materials, or equipments

OBJECTIVES OF METHOD STUDY

- To study the existing proposed method of doing any job, operation or activity
- To develop an improved method to improve productivity and to reduce operating costs
- To reduce excessive material handling or movement and thereby reduce fatigue to workmen
- To improve utilization of resources
- To eliminate wasteful and inefficient motions
- To standardize work methods or processes, working conditions , machinery, equipments and tools.

ADVANTAGES

- Less fatigue to the operator
- Optimum utilization of all resources
- Higher safety to work men
- Shorter production cycle time
- Higher job satisfaction
- Reduced material consumption and wastages
- Reduced manufacturing cost and higher productivity

- Select job/process to be examined & observe current performance

  -high process cost, bottlenecks, tortuous route, low productivity, erratic quality

- Record & document facts

  -activities performed

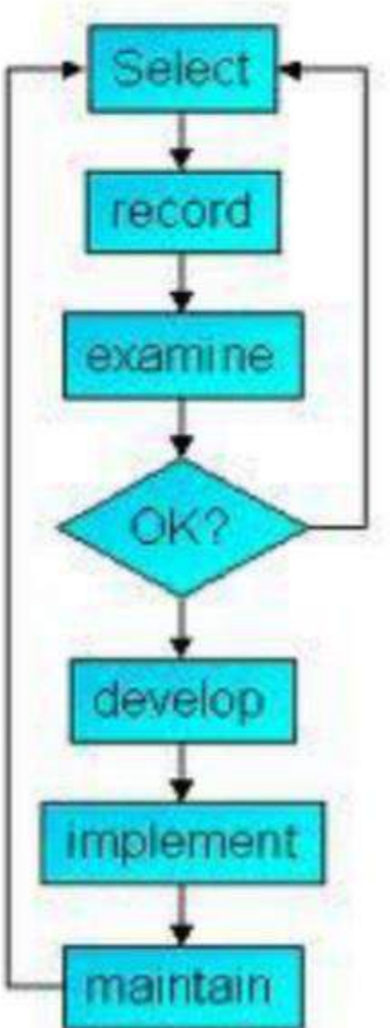
  -operators involved - how etc

  -equipment and tools used

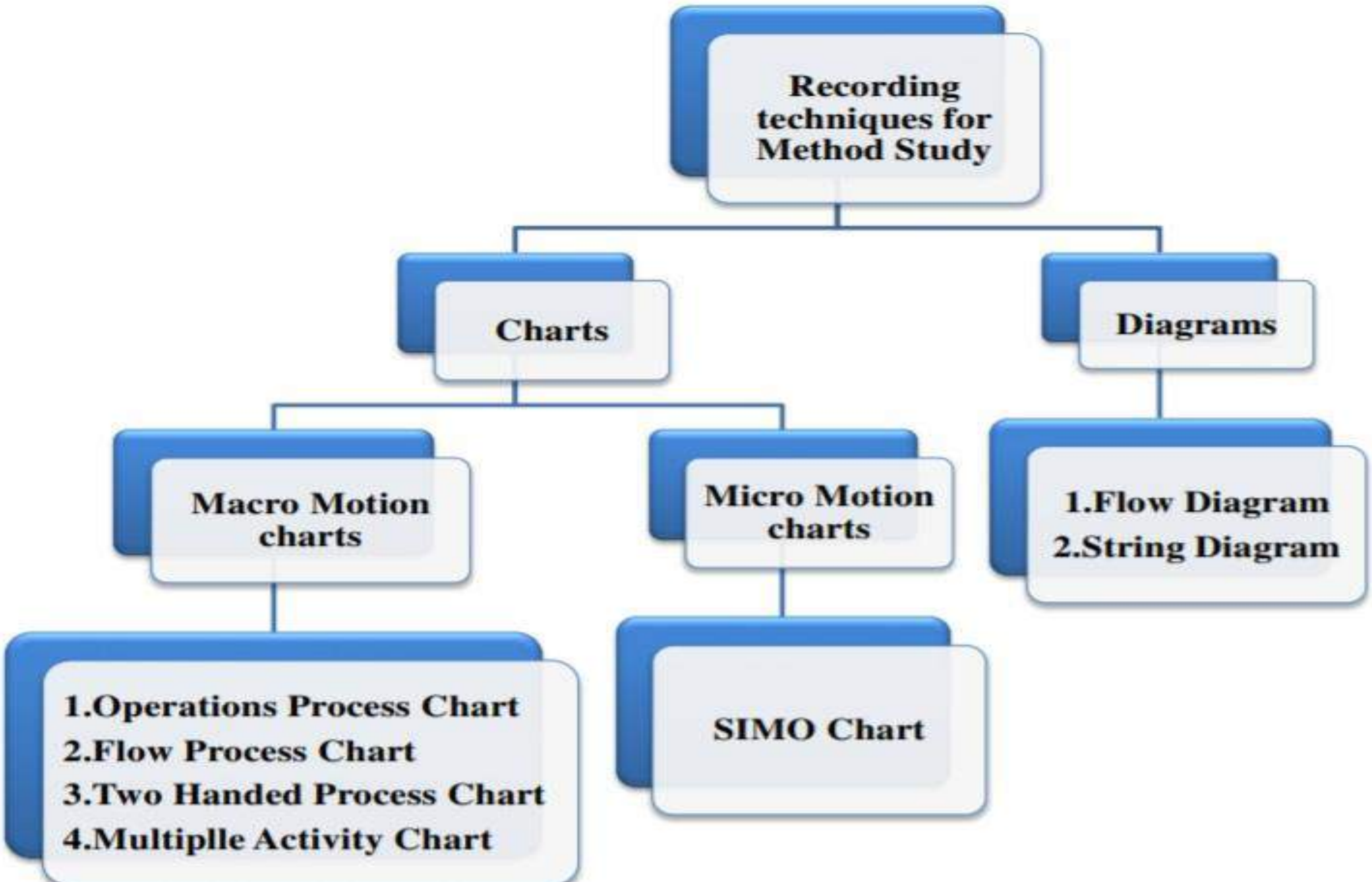
  -materials processed or moved

Contd,

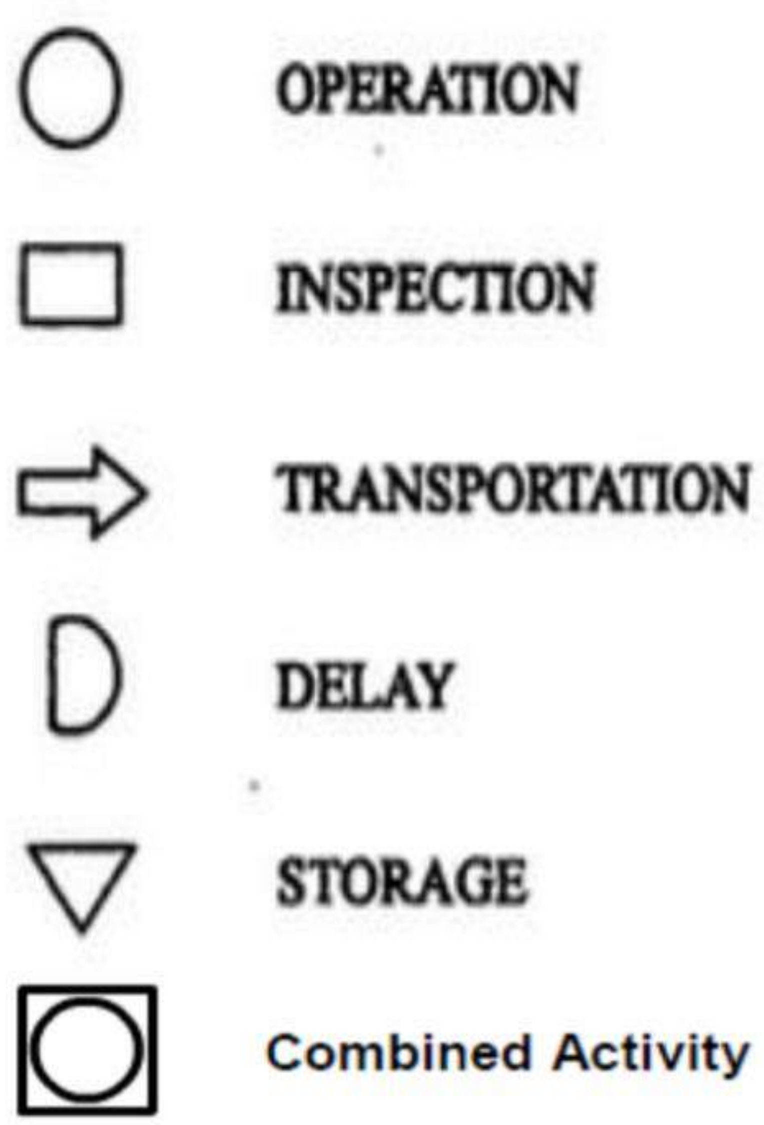
- Apply critical examination - challenge job components & necessity (purpose, place, sequence, method
- Develop alternative methods & present proposals
- Document as base for new work system
- Install, monitor (slippage) & maintain



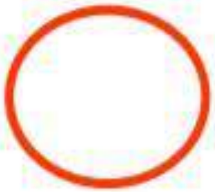
RECORDING TECHNIQUES



METHOD STUDY SYMBOLS



1.Operation



Indicates the main steps in a process, method or procedure. Usually the part, material or product concerned is modified or changed during the operation.

2.Inspection

Indicates an inspection for quality and / or check for quantity

3.Transport

Indicates the movement of workers, materials or equipment from place to place

4.Temporary Storage or Delay

Indicates a delay in the sequence of events : for example, work waiting between consecutive operations, or any object laid aside temporarily without record until required.

5.Permanent Storage

Indicates a controlled storage in which material is received into or issued from a store under some form of authorization; or an item is retained for reference purposes.

6.Combined Activities

Indicates a controlled storage in which material is received into or issued from a store under some form of authorization; or an item is retained for reference purposes.

Example

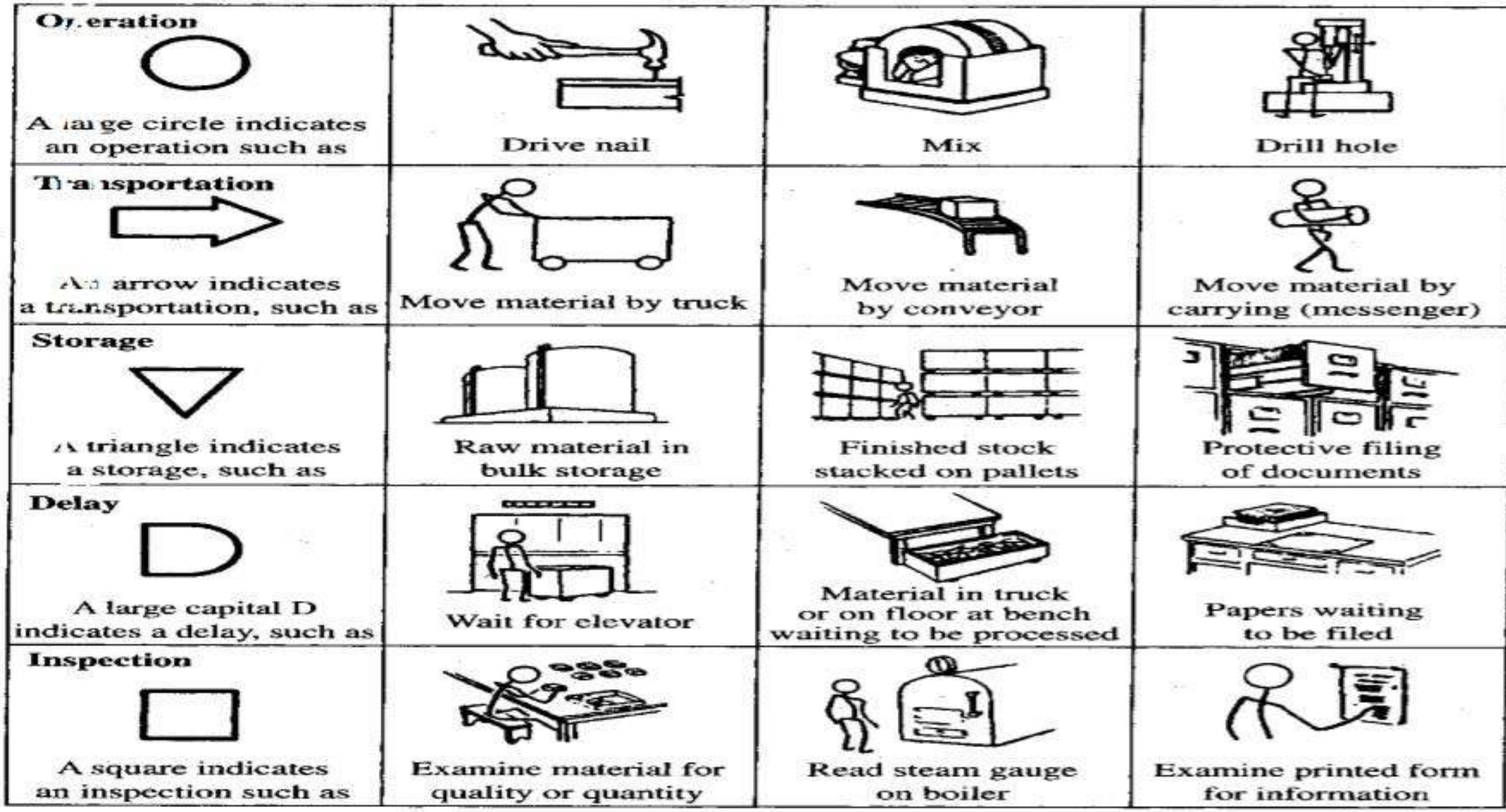
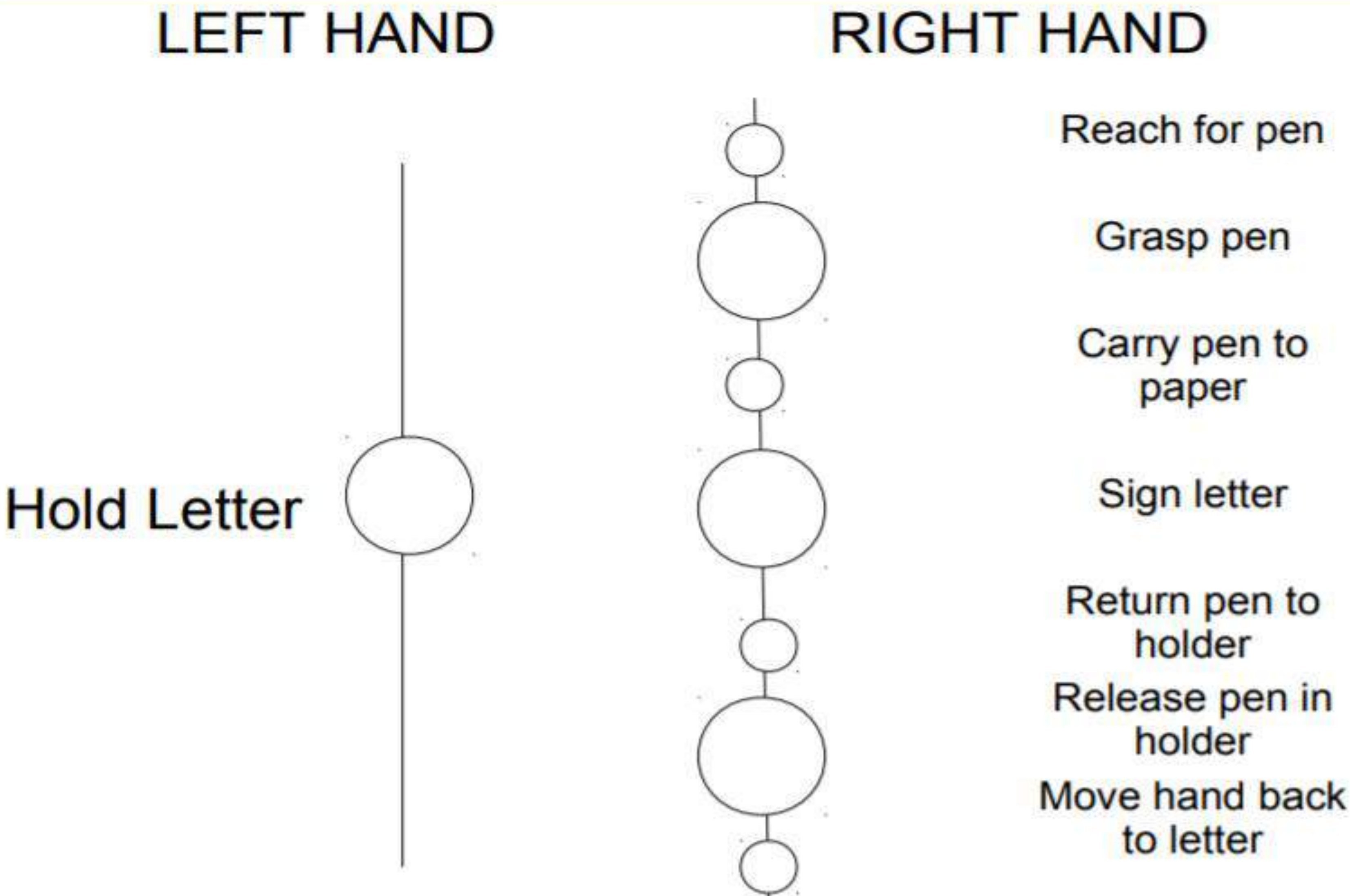


Figure:l The ASME standard set of process chart symbols.


LEFT HAND
RIGHT HAND
Reach for pen
Grasp pen
Carry pen to paper
Hold Letter
Sign letter
Return pen to holder
Release pen in holder
Move hand back to letter

Two handed chart

- A two handed (operator process chart) is the most detailed type of flow chart in which the activities of the workers hands are recorded in relation to one another.

- The two handed process chart is normally confined to work carried out at a single workplace.

- This also gives synchronized and graphical representation of the sequence of manual activities of the worker. The application of this charts are:
  i. To visualize the complete sequence of activities in a repetitive task.
  ii. To study the work station layout.

Two - Handed Process - Chart (Present Method)
Job – Assembly of Nuts and Bolts
Chart begins – Both hands free before assembly
Charted ends – Both hands free after assembly
Charted by – Vivek Mishra
Date of charting – 06 oct. 2005

LEFT HAND		RIGHT HAND	
Description	**Symbol**	**Symbol**	**Description**
Reach for bolt	1 ⇨	1 ⇨	Reach for nut
Grasp bolt head	○ 1	○ 1	Grasp nut
Carry to central Position	2 ⇨	2 ⇨	Carry to central position
Hold Nut	▽ 1	○ 2	Place nut on bolt
Transfer Assembly to right - hand	○ 2	○ 3	Screw nut
	D 1	○ 4	Grasp assembly
		3 ⇨	Carry to box
		○ 5	Release assembly
Return hand to central position	3 ⇨	4 ⇨	Return hand to central position

Summary

Symbol	○	⇨	▽	D
Frequency (RH)	5	4	–	–
Frequency (LH)	2	3	1	1

UNIT 8 TIME STUDY – WORK MEASUREMENT

Structure

8.1 Introduction

Objectives

8.2 Work Measurement and Time Study

8.3 Time Study Equipment

8.4 Performance Rating

8.4.1 Westinghouse System of Rating

8.4.2 Synthetic Rating

8.4.3 Objective Rating

8.4.4 Skill and Error Rating

8.4.5 Physiological Evaluation of Performance Level

8.5 Allowances

8.5.1 Interference Allowance

8.5.2 Relaxation Allowance

8.5.3 Process Allowance

8.5.4 Contingency Allowance

8.5.5 Special Allowance

8.6 Predetermined Motion Time Standards

8.6.1 Work Factor System

8.6.2 Method Time Measurement

8.6.3 Basic Motion Time Study

8.7 MOST

8.8 Work Sampling

8.8.1 Objectives

8.8.2 Procedure

8.8.3 Number of Cycles to be Timed

8.8.4 Applications of Work Sampling

8.8.5 Advantages of Work Sampling Over Time Study

8.8.6 Disadvantages

8.9 Summary

8.10 Key Words

8.11 Answers to SAQs

8.1 INTRODUCTION

'Time is money', whether it is observed by anybody or not, it is definitely followed by any industrial engineer through the time study and work measurement. The work is measured in terms of certain time elements for which the remuneration is suitably designed. According to F. W. Taylor, any work can be split into small units called 'elements'. These elements are timed. Such times are standardised by suitable measurement technique, with the help of which the targets are fixed. The targeted job is then called 'task'. In Taylor's words the worker is to be provided by three basic 'definite' requirements – Definite Time, Definite Task and Definite Method so as to perform a job in most efficient and effective way.

Objectives

After studying this unit, you should be able to

- understand the time study and conduct a time study,
- rate a job and a worker doing certain job,
- calculate the basic time, normal time and standard time of a job or element, and
- fix the target for job.

8.2 WORK MEASUREMENT AND TIME STUDY

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

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

As Defined

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

and,

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

(Definition according to ILO)

8.3 TIME STUDY EQUIPMENT

The following equipments commonly are used for conducting time study.

(a)	Stopwatch	:	to record time
(b)	Time study board	:	for affixing time study forms
(c)	Time study forms	:	affixing on board (formats are shown)
(d)	Pencils and erasers	:	for entering values
(e)	Calculator	:	calculating equipment
(f)	Measuring tape	:	measuring equipment for length
(g)	Steel rule	:	measuring equipment for lengths
(h)	Micrometer	:	measuring equipment for small lengths

(i) Spring balance : measuring equipment for weights

(j) Tachometer : measuring equipment for speeds

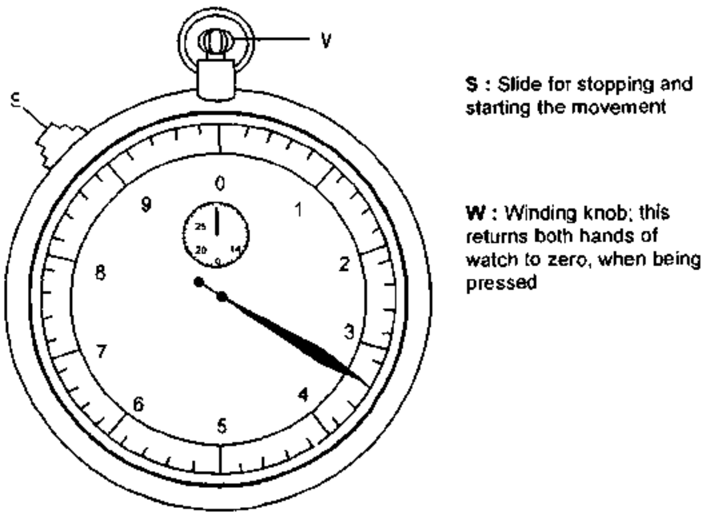


Figure 8.1 : Stop Watch

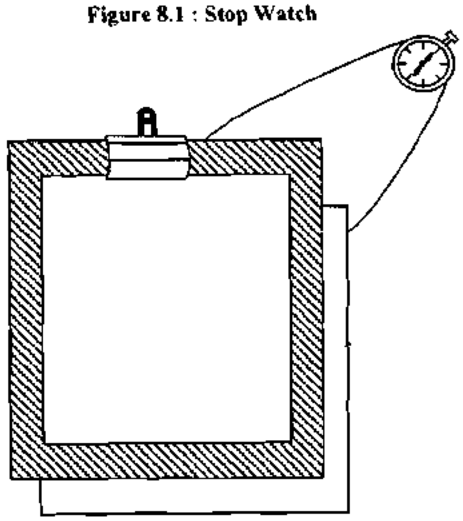


Figure 8.2 : Time Study Board

Time Study Sheet

(Note : Work Place layout is to be drawn on the backside of time study sheet)

Department : .... Department code : ....

Operator : .... Employment No. : ....

Operation : .... Drawing No. : ....

Machine : .... Machine No. : ....

Product : .... Part No. : ....

Material : .... Tools/Guages : ....

Clock No. : .... Study No. : ....

Study conducted by : .... Date of Study : ....

Checked by : .... Date of Checking : ....

Approved by : .... Date of Approval : ....

Element Description	Rating	Reading on Stopwatch	Time Taken	Basic Time

Cycle Time Study Sheet

(Note : Work place layout is to be drawn on the backside of cycle time study sheet)

Department : .... Department code : ....

Operator : .... Employment No. : ....

Operation : .... Drawing No. : ....

Machine : .... Machine No. : ....

Product : .... Part No. : ....

Material : .... Tools/Guages : ....

Clock No. : .... Study No. : ....

Study conducted by : .... Date of Study : ....

Checked by : .... Date of Checking : ....

Approved by : .... Date of Approval : ....

Sl. No.	Element Description	Reading on Stopwatch (Observed Time)										Avg. Time Taken	Rating	Basic Time
		1	2	3	4	5	6	7	8	9	10			

Steps in conducting time study :

Step 1

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

Step 2

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

Step 3

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

Step 4

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

Step 5

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

$$\text{Normal time} = \text{Basic time} \times \text{Rating factor}$$

Step 6

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

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

Recording Necessary Information

(a) Information regarding the job :

(i) Name of the product

(ii) Name of the part and number according to drawing

(iii) Material

(iv) Quality

(v) Quantity of the part per product

(b) Information regarding the process :

(i) Location of work place

(ii) Sequence of operations

(iii) Complete specification of the machine

(iv) Tooling

(v) Speeds, feeds and rate of production, etc.

(vi) Work place layout

(c) Information regarding the worker :

(i) Name of the worker

(ii) Education

(iii) Experience

(iv) Level of skill

(v) Worker's competence

(d) Information regarding the working conditions :

(i) Temperature – minimum and maximum

(ii) Humidity

(iii) Economical factors

(iv) Lighting

(v) Level of sound

(vi) Weather conditions

(vii) Dust

Breaking the Job into Elements

(a) Examine the method employed and carry out the operation to ensure whether it is efficient method.

(b) Describe the complete process after checking

(c) Break the operation into elements. While breaking the job into elements. only one work cycle should be taken into account. An element is defined as "a distinct part of the specified job selected for convenience of observation, measurement and analysis". For example, "turning operation" on a lathe machine, the elements are like this

   (i) Job fixing in the 3 or 4 Jaw Chuck,

   (ii) Tool setting/centering,

   (iii) Turning the job, and

   (iv) Removing the job from chuck.

(d) The selection of elements should fulfill the following characteristics :

   (i) Duration of every element should be as short as possible but, it should be able to be timed accurately.

   (ii) Man controlled elements (handling time) should be separated from machine controlled elements (machining time).

   (iii) Repetitive and non-repetitive elements must be clearly demarcated.

   (iv) There should be a clear distinction between the effective (productive) and ineffective (non-productive) time elements.

   (v) The constant elements, which are independent of size, shape, weight, etc. of work should be separated from the variable elements.

Timing each Element

Each element is timed by using a stopwatch either in continuous method (cumulative timing) or snapback method (fly back timing). Although both methods are equally efficient in working, there is a chance of loss of time in fly back timing while resetting it to zero. Hence the former is supposed to be more accurate while the latter reduces clerical work and hence the costs. However, the element is performed several times and the time is recorded. The average of these timings is then calculated to find the normal time.

Let us now take a numerical example to demonstrate this :

A cycle consisting of five elements in a working cycle has yielded the following timings on the stopwatch

Element Number	Stopwatch Reading in 100^{th} of a Minute	Element Time (in 100^{th} of a Minute)
1	15	15
2	35	20
3	72	37
4	108	36
5	152	44

Example 8.1

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

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

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

Solution

For Element 1

Normal Time = Observed time × Rating Factor

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

Standard Time = 0.56

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

For Element 2

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

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

For Element 3

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

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

For Element 4

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

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

For Element 5

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

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

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

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

SAQ 1

(a) What do you understand by time study and work measurement?

(b) Explain the systematic procedure of time study.

(c) Describe the equipment used for conducting time study.

(d) A job has been sub-divided into 4 elements. The time for each element and respective rating are given below :

Element Number	Observed Time	Rating Factor %
1	0.6	100
2	1.0	80
3	1.2	130
4	1.5	90

Calculate the normal time and standard time for each element and for the job if the allowance is 5%.

(e) The observed time for an element is 2 minutes. The rating factor is 80%. If standard time is 1.76, how much allowance is given for the element?

Activity 1

Conduct a time study for the following :

(a) Toasting of a bread.

....

....

....

(b) Juice making.

....

....

....

(c) Crimpling a cap on a cool drink bottle.

....

....

....

(d) Thread cutting operation on lathe.

....

....

....

(e) Assembling of nut and bolt.

....

....

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8.4 PERFORMANCE RATING

The Society of Advancement of Management (SAM) national committee defines the performance rating as "the process during which the time study engineer compares the performance of the operator under observation with the observer's own concept of proper (normal) performance. It can also be considered as the efficiency of the worker.

$$\text{The Performance Rating or Efficiencty} = \frac{\text{Observed performance}}{\text{Normal performance}} \times 100$$

The time taken for a job varies from person to person attributed to various reasons such as environmental factors and human factors discussed in motion study (Unit 10 of this block). Sometimes, we come across some complaints such as the worker is intentionally doing delay or the observer's judgement is prejudiced. To overcome such disputes, the normal rating is compared with performance rating to standardise the time and thence fix up the target of an element or job.

Various systems of performance rating are as follows :

(a) Westinghouse system of rating

(b) Synthetic rating

(c) Objective rating

(d) Skill and effort rating

(e) Physiological evaluation of performance level.

8.4.1 Westinghouse System of Rating

This system is based on four factors :

(a) Skill

(b) Effort

(c) Condition

(d) Consistency

Various ratings are tabulated in the Table 8.1 as given by Westinghouse. The actuals are compared and suited with one of the ratings in each of the above four factors and summed up for finding total rating. This is added (or subtracted) to unity to find the rating factor. On multiplying with the actual (Observed) time, we get Normal or Basic time. The standard time is then calculated by adding allowances to the normal time. This is illustrated through the numerical problems given below.

Table 8.1 : Westinghouse Performance Rating Table

Factor → Grade ↓	Skill (1)	Effort (2)	Conditions (3)	Consistency (4)
Super (1)/Excessive(2)/ Ideal(3)/Perfect(4)	$A_1 = +0.15$ $A_2 = +0.13$	$A_1 = +0.13$ $A_2 = +0.12$	$A = +0.06$	$A = +0.04$
Excellent	$B_1 = +0.11$ $B_2 = +0.08$	$B_1 = +0.10$ $B_2 = +0.08$	$B = +0.04$	$B = +0.03$
Good	$C_1 = +0.06$ $C_2 = +0.03$	$C_1 = +0.05$ $C_2 = +0.02$	$C = 0.02$	$C = 0.01$
Average	D = 0.00	D = 0.00	$D = 0.00$	$D = 0.00$
Fair	$E_1 = -0.04$ $E_2 = -0.10$	$E_1 = -0.04$ $E_2 = -0.08$	$E = -0.03$	$E = -0.02$
Poor	$F_1 = -0.16$ $F_2 = -0.22$	$F_1 = -0.12$ $F_2 = -0.17$	$F = -0.07$	$F = -0.04$

Summarised formula for calculation :

Westinghouse rating = Sum of ratings, i.e. rating of (Skill + Effort + Conditions + Consistency) as given in Westinghouse tables.

Rating Factor = 1 ± Westinghouse Rating

Normal Time = Observed time × Rating factor

$$\text{Standard Time} = \text{Normal Time} \times \frac{100}{(100 - \text{Total allowances in percentage})}$$

Example 8.2

The observed time for an element was one minute and the rating were found to be as follows :

Skill	:	Fair	E_1
Effort	:	Excessive	A_1
Condition	:	Good	C
Consistency	:	Excellent	B

Determine the normal time or basic time for the element under observation. (Refer Westinghouse performance rating table). Also find the standard time @ 20% allowance.

Solution

From the Performance Rating tables of Westinghouse system:

Skill	Fair	E_1	0.04
Effort	Excessive	A_1	0.13
Condition	Good	C	0.02
Consistency	Excellent	B	0.03
Overall (Total) Rating			0.22

i.e. positive rating by + 0.22 over unity = 1 + 0.22 = 1.22

∴ Normal Time = Observed Time × Rating Factor

$$= 1 \times 1.22 = 1.22 \text{ min}$$

$$\text{Standard Time} = 1.22 \times \left(\frac{100}{100-20}\right) = \frac{1.22}{0.8} = 1.525 \text{ min.}$$

Example 8.3

Find the Normal Time and Standard Time for an element, which has the following ratings in Westinghouse system, and observed time is 1.2 minute.

Skill	Average
Effort	Average
Condition	Fair
Consistency	Poor
Allowance	10%

Solution

From the Performance Rating tables of Westinghouse system;

Skill	Average	0.00
Effort	Average	0.00
Condition	Fair	– 0.03
Consistency	Poor	– 0.04
Total (Overall) Rating		– 0.07

i.e. negative rating by – 0.07 under unity = 1 – 0.07 = 0.93

∴ Normal Time = Observed Time × Rating Factor

$$= 1.2 \times 0.93 = 1.116 \text{ min}$$

$$\text{Standard Time} = 1.116 \times \frac{110}{100-10} = 1.24 \text{ min.}$$

SAQ 2

(a) Find the standard time for an element of one minute observed as average in all the factors of Westinghouse system and 15% allowances are given.

(b) The observed time for an element was one minute and the rating were found to be as follows :

Skill	Super	A_1
Effort	Fair	B_2
Condition	Ideal	A
Consistency	Average	D

Determine the normal time or basic time for the element under observation. (Westinghouse performance rating table will be provided).

(c) Calculate normal time for an element of 2 minutes with skill, effort. condition and consistency as 0.11, 0.05, – 0.03 and 0.00, respectively.

(d) The following observations of actual time taken by worker for doing a job repeatedly were taken by a time study observer. The rating were found to be as follows :

Skill	Good	C_1
Effort	Excessive	A_1
Condition	Excellent	B
Consistency	Poor	F

Observation No.	1	2	3	4	5	6
Time in Minutes	0.2	0.3	0.4	0.6	0.4	0.2

Determine the normal time or basic time for the element under observation. (Refer Westinghouse performance rating table).

[**Hint** : Take actual time of an average time of the six observations.]

8.4.2 Synthetic Rating

This system of rating was introduced by Morrow. The time study observer records the actual time of performance for the element as done in the previous method. Performance times for such elements have been standardised, which are known as "Predetermined Motion Time Standard Values" or 'PMTS Values'. The PMT value for the elements from such tables are noted. The ratio of Predetermined Motion Time Standard value of the element (taken from tables) to Average Actual Time (Observed Time) for the same element gives the Rating Factor.

Summarily this is expressed as

$$R = \frac{P}{A}$$

where, R = Performance Rating Factor,

P = Predetermined Motion Time Standard value for the element in minutes (from tables), and

A = Average Actual Time (Observed) for the same element in minutes.

Example 8.4

The average actual time for 6 elements of a task were measured and tabulated below. The Predetermined Motion Time for two elements is also given. Calculate the performance rating factor. Also find the normal times for all the elements on the basis of average rating.

Element No.	1	2	3	4	5	6
Average Actual Time (A)	0.5	0.6	0.5	0.4	0.3	0.6
Predetermined Motion Time (P)	0.45			0.46		

Solution

$$\text{Performance Rating } (R) = \frac{P}{A} = \left(\frac{0.45}{0.5}\right) \times 100 = 90\% \text{ for first element.}$$

$$\text{Performance Rating } (R) = \frac{P}{A} = \left(\frac{0.46}{0.4}\right) \times 100 = 115\% \text{ for fourth element.}$$

$$\text{Average } R = \frac{(115 + 90)}{2} = 102.5\%$$

Normal Times for the elements are

Element No.	**Actual Time**	**Normal Time (Actual Time × Average Rating)**
1	0.5	0.5 × 102.5 = 0.5125
2	0.6	0.615
3	0.5	0.5125
4	0.4	0.41
5	0.3	0.0375
6	0.6	0.615

8.4.3 Objective Rating

It was proposed by M.E. Mundel and is carried out in two steps.

Step 1

The speed or pace of the operator is rated against an objective pace standard. This objective pace standard is same for all the jobs irrespective of the job difficulty and its limiting effect on pace. Mundel uses the term 'Base Time' for this time rated against pace.

$$B = P \times T$$

where, B = Base Time,

P = Rated Pace, and

T = Observed Time.

Step 2

Now, the numerical obtained in step 1 is appraised by an adjustment factor, which Mundel calls job difficulty factor or job complexity or secondary adjustment.

Thus, it is expressed as

$$\text{Normal Time } (NT) = B \times M$$

where, B = Base time ($P \times T$), and

M = Job Difficulty Factor.

After calculating normal time, standard time can be found by usual method as

Standard Time (ST) = Normal Time (NT) + Allowances (A)

Job difficulty is measured based on six factors as given in Table 8.2.

Table 8.2 : Job Difficulty Factors

Sl. No.	Description	Ref. Letter	Conditions	Percent Adjustment
1	Amount of body used	A	Finger used loosely	0
		B	Wrist and Fingers	1
		C	Elbow, wrist and fingers	2
		D	Arm, etc.	5
		E_1	Trunk, etc.	8
		E_2	List with leg from floor	10
2	Food pedals	F	No pedals or one pedal with fulcrum under foot	0
		G	Pedal or pedals with fulcrum outside the foot	5
3	Bi-manualness	H_1	Hands help each other or alternate	0
		H_2	Hands work simultaneously doing the same work	18
4	Eye hand coordination	I	Rough work, mainly feet	2
		J	Moderate vision	2
		K	Constant but not closed	4
		L	Watchful, fairly close	7
		M	Within 1/64″	10
5	Handling requirements	N	Can be handled roughly	0
		O	Only groll control	2
		P	Must be controlled but may be squeezed	3
		Q	Handle carefully	4
		R	Fragile	5
6	Weight		Identified by the actual weight for resistance	

Summary

Base Time = Pace Rating × Observed Time (P.T)

Normal Time = Base Time × Secondary Adjustment (B.M) = PMT

Standard Time = N + A = PMT + A

Example 8.5

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

Solution

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

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

$$\text{Standard Time} = 1.872 \times \frac{110}{100-10} = 2.08 \text{ min.}$$

Example 8.6

An Element is observed to be carried out in 0.8 minutes. Given pace rating is 110% and the secondary adjustment by 20%, find the time on any fair day. If 0.2 minute per element is given as allowance, what is the standard time taken for 20 repeated actions?

Solution

$$\text{Base Time} = 0.8 \times \frac{110}{100} = 0.8800$$

$$\text{Normal Time} = 0.88 \times \frac{120}{100} = 1.056$$

$$\text{Standard Time} = 1.056 \times \frac{100}{100 - 20} = 1.32 \text{ min.}$$

Time taken for 20 actions $= 20 \times 1.32 = 26.4$ minutes.

SAQ 3

(a) The observed time for an element is 0.4 minute and the pace rating is 90% and the sum of all secondary adjustments amount to 20%. Find the normal time.

(b) The observed time of an element is 0.7 minute and the pace rate is 80%. If the normal time is decided as 0.73 minute, find what percent of adjustment is added towards job difficulty.

8.4.4 Skill and Effort Rating

This system was introduced by Charles E. Bedaux in 1961 and is also known as Bedaux system. In this system, the observer is supposed to evaluate the work rate or speed of worker's movement and how fast he is performing the motions, but not the movements and skill he is applying. Unlike the other methods Bedaux introduced a unit "*B*" that represents a standard minute, which is composed of

(a) work component

(b) relaxation component

The procedure is as follows :

(a) Divide the operation into smallest measurable elements (smallest time is ≥ 3 seconds).

(b) Time the element with the help of a stopwatch having sixty divisions on its dial.

(c) Take sufficient observations and calculate average time.

(d) Estimate the efficiency of the operator in terms of *B* values assuming the average worker must obtain 60B per hour and maximum *B* value can be 80 *B* per hour. Thus convert the observed time in terms of *B*'s with reference to a standard of 60 *B* per hour values.

(e) Allow the relaxation factors as shown in Table 8.3.

Table 8.3 : Relaxation Factors

Light work	1.10 to 1.20
Medium work	1.20 to 1.35
Heavy work	1.35 to 1.50
Very heavy work	1.50 to 3.00

(f) Now calculate B values for work element by the formula

The number of B's per work element = Observed Time × Speed of work × Relaxation Allowance/(60 × 60) = $\left(\dfrac{T_b \times V \times R_a}{60 \times 60}\right)$

where, T_b = Observed time in seconds,

V = Speed of work in terms B's, and

R_a = Relaxation allowance.

(g) The sum of all the values of various work elements gives B values per work piece.

(h) Variable time (lost time) and setting are to be recorded regularly and special B values are to be provided accordingly.

(i) Irregular times and disturbance are not to be included.

(j) Purely machining times where workman is not involved are evaluated separately and added as a method allowance, since only human effort is measured by the Bedaux system.

Example 8.7

For a work element, the observed time was 10 seconds and the speed is found to be 60 points on Bedaux's scale. If the job is a heavy work for which a relaxation allowance is given as 1.20, find the B value for the element.

Solution

$$B \text{ value } = \left(\frac{T_b \times V \times R_a}{60 \times 60}\right)$$

$$= \left(\frac{10 \times 60 \times 1.2}{60 \times 60}\right)$$

$$= 0.2\ B$$

SAQ 4

Find the B value of the work element whose relaxation allowance is 1.25 and the worker with 72 B speed is observed to do in 20 seconds.

8.4.5 Physiological Evaluation of Performance Level

It is known fact that there is a relation between the physical work and the amount of oxygen consumed. It has also been tried out to find the changes in heartbeat for various physical works. This is assumed to be most reliable measure of muscular activity and studies are still going on by many experts in industrial engineering, bio-medical engineering and physiology.

However this method is not in much use presently.

Summarising all the above methods we can notice the following formulae in all the systems : (Except Bedaux's skill and effort system)

Normal Time = Observed Time × Rating Factor

Standard Time = Normal Time × Allowance Factor

$$\text{Allowance Factor} = \frac{100}{100 - \text{allowance in percentage}}$$

This is diagrammatically shown in Figure 8.3.

Observed Time	Rating Factor	Work Delay	Constant Allowance	Relaxation Allowance
Observed Time				
	Basic Time			
		Normal Time*		
			Work Content	
				Standard Time

Figure 8.3 : Standard Time

*Normal Time and Basic Time are usually taken in the same sense if the work delay is not considered or negligible (when there is no work delay, both are equal).

8.5 ALLOWANCES

The determination of allowances is the most controversial part of the time study, because it varies from person to person, situation to situation, place to place, job to job, season to season and many more. Therefore the industrial engineer feels it most difficult job. However, certain standardised norms of allowances are in regular practice by the industrial engineers. These are narrated under five heads as follows :

(a) Interference allowance

(b) Relaxation allowance

(c) Process allowance

(d) Contingency allowance

(e) Special allowance

8.5.1 Interference Allowance

This is provided on a job where the operator is working on several machines. The machine interference may occur due to settings, positioning, etc. which may influence the skill and effort of the operator. However, this may not be added always for calculating standard time as it belongs to machine controlled element.

8.5.2 Relaxation Allowance

In every computation of standard time, this allowance must be considered for manual work, irrespective of the nature of the job. The relaxation allowances are usually expressed in percentage of normal time.

British Standards Institution (BSI) has defined relaxation allowances as follows, which are world-wide accepted :

(a) 3138 : 1959

35004 – Relaxation Allowance (R. A.) – Compensating rest allowance.

An addition to the basic time intended to provide the worker with the opportunity to recover from the physiological effects of carrying out specified conditions and to allow attention to personal needs. The amount of allowance will depend on the nature of the job.

(b) **35005 – Fatigue Allowance** – A sub-division of relaxation allowance intended to cater for the physiological and psychological effects of carrying out specified work under specified conditions.

(c) **35006 – Personal Need Allowances** – A sub-division of the relaxation allowance intended to cater for attention to personal needs.

Thus, relaxation allowances is combination of allowances to get relieved from fatigue, to attend personal needs and all other allowances to recover from the physiological and psychological effects. It is very difficult to assess fatigue and the personal needs owing to the reason that the degree of variation is very high. The personal needs or the fatigue are developed as a result against the strains (either physical or mental). These strains are caused by the stresses (either physical or mental) some of which are listed below.

(a) Monotony

(b) Boredom

(c) Intensity of muscular and mental load to put

(d) Duration of muscular and mental loads

(e) Environmental conditions

(f) Responsibilities

(g) Worries

(h) Conflicts

(i) Illness and pains and health condition

(j) Nutrition

(k) Security

(l) Physiological disorders

(m) Psychological disorders

(n) Attitudes and willfulness to work

(o) Nature of job and its intricacy

(p) Accuracy and precision required for the job

(q) Risk

(r) Other personal needs due to natural phenomena

All the above stated reasons of stresses that cause strain in human body or mind will be tolerable to certain limit. The Hooke's law is also applicable here (the stress is directly proportional to the strain up to certain limit called Elastic limit) but the relation is nonlinear and complicated in this case. Hence, it is better to avoid, as far as possible. Because of this reason certain large-scale companies are providing all the amenities, facilities and fulfill every need to make them free from all the stresses and concentrate more on work. They also will be given the suitable rest pauses and refreshments so that the fatigue may not be developed or may be relieved if developed. The soldiers of army, etc. are good examples to quote here. Of course, they will be so trained to withstand the fatigue too.

8.5.3 Process Allowance

When an operator is running an automatic machine, he becomes idle after loading or if the process demands some time to go for next operation such as allowing cooling after welding operation, he becomes idle. In such cases this allowance becomes prominent.

Depending on the situations, Indian industries are using the index of process allowance as shown in Table 8.4.

Table 8.4 : Process Allowances

25% of Normal Time	Heavy work load (30 kg)
20% of Normal Time	Short cycle load (0.2 min.)
15% of Normal Time	Similar type of work load
10% of Normal Time	Power fed machine operation
5% of Normal Time	Operation on automatic machine

8.5.4 Contingency Allowance

It is often expressed as percent of basic time and is less than 5% if recommended by the observer. According to British standards, it is a small allowance to meet legitimate expected items of work or delays. The accurate measurement of this time is not worthwhile and uneconomical as it occurs irregularly and rarely.

8.5.5 Special Allowance

These include all the other allowances such as policy allowances and others given by the company such as when a new job is given to worker, he takes time to learn, a relief allowance given to operators to facilitate their leader to address on a certain occasion, etc.

SAQ 5

(a) Explain various allowances provided to the operators working in industry.

(b) Give short notes on

  (i) Westinghouse rating system

  (ii) Skill and effort rating system

  (iii) Objective rating system

  (iv) Synthetic rating system

(c) Distinguish between Observed Time, Normal Time and Standard Time.

Activity 2

(a) Go to an industry in your vicinity and interview a few people to identify the various allowances provided by the management.

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(b) In the same industry conduct the performance rating and Westinghouse rating system.

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8.6 PREDETERMINED MOTION TIME STANDARDS (PMTS)

If you have to assess certain activity or a job you need some standard with which you compare, so also, for an element of a work study. Anything rated as good, better, normal, average, fair, poor, bad, worse or worst are all relative terms, which evolve by comparing with a standard data. In the present context of time study, to standardise the time of an operation we need to divide the job into small work elements, which are to be repeated in various combinations. The time values of these work elements are then established accurately to make use of these without any further time study, whenever such element occurs. This is known as standard data for all further references. However, all this standardisation is to be done if standardised method exists, otherwise the method is to be standardised first.

Methods of Determining PMTS

The following PMTS systems are in common practice :

(a) Work Factor System (WFS)

Developed during 1940, J. H. Quick, W. J. Shea and R. E. Kohler.

(b) Method Time Measurement (MTM)

Developed by Method Engineering Council of Pittsburgh, Pennsylvania.

(c) Basic Motion Time Study (BMTS)

Developed by J. D. Woods and Gordon Ltd., Toronto, Canada.

(d) Motion Time Analysis (MTA)

Developed by Segur in 1930.

(e) Dimensional Motion Time Study (DMTS)

Developed by Bridgeport, Connecticut Plant.

Now let us discuss the above methods in detail.

8.6.1 Work Factor System (WFS)

We cannot compare a horse with a donkey just by the virtue of both being four-legged mammalian animals. Similarly, all works cannot be measured with same scale and same formula of efficiency (output/input), since there are many factors involved.

For example, there are two lecturers teaching two subjects, say *X* teaches technical subject and *Y* teaches a management subject. Now, if we have to decide who is better, it is not an easy job. Even though various factors attributed to human factors such as ability to explain, gestures, postures, style, language, moods, perceiving capacity of students, health conditions and environmental conditions are kept constant, the subject complexity itself is another variable that play a major role here. In a good number of occasions we come across rating the lecturers by student pass percentage or number of ranks obtained in the examination. But think, how far it is justified. There are many variables that can be accounted here. The students might not have concentrated in learning the subject, the question paper could be tough, the questions might have mislead or out of syllabus, the evaluator might have expected a different way of answering and many more reasons like these. The degree of these factors again varies with the persons, subjects, institutions, circumstances and environments. Hence, it is suggested to take average in all combinations and rate each job with its own standard, which can be acceptable as most appropriate with allowing a standard deviation.

In factory works also where physical work is more involved, such situations arise, particularly while calculating the incentive. In such occasions, it is assumed that the time required to perform a task is affected by four factors.

These are :

(a) Body members used such as arm, forearm swivel, trunk, foot, legs, fingers, hand, head, eyes, ears, etc.

(b) Distance moved, measured in terms of centimetres or inches.

(c) Manual control required to eliminate or reduce the difficulties involved such as directional controls, speed controls, stopping and starting, priming and pumping, precautionary measure, etc.

(d) Weight or resistance or loads.

The Work-Factor System recognise some elements of work which are shown in Table 8.5.

Table 8.5 : Elements of Work

Sl. No.	Activity	Symbol	Explanation
1	Assembles	ASY	Putting the objects together
2	Diassembles	DSY	Separating different parts of the assembled unit
3	Transport (Reach and Move)	TRP	Moving an article from one place to another
4	Preposition	PP	Locating an article in predetermined position so that it is ready for use
5	Grasp	GR	Taking hold for something
6	Use	US	Manipulating or causing a tool to do its function
7	Mental Process	MP	Mental work such as planning
8	Release	RL	Releasing an object

The abbreviations/symbols used for body members and work factors applied to perform the above said work elements are shown in Tables 8.6 and 8.7.

Table 8.6 : Symbols of Body Members

Sl. No.	Activity	Symbol
1	Arm	A
2	Finger	F
3	Hand	H
4	Force Arm Swivel	FS
5	Trunk	TR
6	Foot	FT
7	Leg	L
8	Head Turn	HT

Table 8.7 : Symbols of Work Factor

Sl. No.	Work Factor	Symbol
1	Weight or Resistance	W
2	Steer or Directional Control	S
3	Precaution or Care	P
4	Change Direction	U
5	Definite Stop	D

The values of each motion times for every body member for various work factors are available from Work Factor – Motion timetables. For example a table for arm is given in Table 8.8.

Table 8.8 : Values for Arm Motions

Distance Moved in Inches	Basic Time	Number of Work Factors			
		1	2	3	4
1	0.018	0.026	0.034	0.040	0.046
10	0.042	0.061	0.078	0.093	0.107
20	0.054	0.080	0.102	0.124	0.144
30	0.070	0.096	0.199	0.142	0.163

How to read or represent above table values to record the analysis :

(a) Suppose a small coin is tossed 25 cm (10")

This is only a basic motion, therefore it represented as A10 (means Arm has a basic motion moved 10"), its table value is read as 0.042 minutes.

(b) Suppose reaching 75 cm (30") to a part in a tray.

This motion consists one work factor, i.e. definite stop motion of Arm for 30", so it represented as A30D and the value is read as 0.096.

(c) Suppose move 1.5 kg box 50 cm (20") from pile to work table.

This motion is composed of two work factors viz. Weight and Definite stop by Arm for 20" distance, hence it is represented as A20WD whose value is 0.102.

8.6.2 Method Time Measurement (MTM)

MTM has been recognised by methods engineers as a powerful tool for work simplification, since the publication of the book, *Methods-Time Measurement*, in 1948.

The procedure of MTM is defined as :

> *"The procedure, which analyses any manual operation or method into the basic motions required to perform it and assigns to each motion a Predetermined Motion Time Standard (PMTS), which is determined by the nature of motion under which it is made".*

MTM was developed from the studies of motion pictures on industrial operations and time standards were calculated in the Time-Motion Units known as TMU.

1 TMU = 0.0006 minutes.

MTM is the tool of method analysis, which provides answers in terms of time without any use of stopwatch.

MTM Fundamental Motions

(a) Eight Basic Motions

(i) Reach (R)

(ii) Move (M)

(iii) Apply pressure (Ap)

(iv) Turn (T)

(v) Grasp (G)

(vi) Position (P)

(vii) Disengage (D)

(viii) Release Load (RL)

(b) Nine Pedal (Legs) and Trunk Motions

(i) Side up step (SS)

(ii) Turn Body (TB)

(iii) Walk (W)

(iv) Bend (B)

(v) Stop (S)

(vi) Kneel on One leg (KOK)

(vii) Kneel on Both legs (KBK)

(viii) Foot Motion (FM)

(ix) Sit (SIT)

(c) Two Eye Motions

(i) Eye Travel Time

(ii) Eye Focus Time

In each of the above motions, there are various classes depending on the efforts and work contents and is represented accordingly. For example R5C means Reach 5" of Class C. Thus these are read and compared.

Applications of MTM

There are numerous uses of MTM of which a few are listed below :

(a) Establishment of time standards.

(b) Improvement in existing/prevailing methods.

(c) Estimating costs.

(d) Development of tool design.

(e) Selection of effective equipment.

(f) Development of effective method.

(g) Advance planning.

(h) Aiding product design and product renovation or new product development.

(i) Training operators and supervisors to make them method and time conscious.

(j) Provides a good basis for settlement of grievances in wage rate.

Activity 3

Draw MTM for "Removing pen from your pocket and keep ready to write", in the form of a SIMO chart or Two-handed Process chart, with the columns as Left Handed movement description, Symbol, Limiting time, Right Handed description and Symbol.

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8.6.3 Basic Motion Time Study (BMTS)

This system was developed during 1950 by Ralph Presgrave, G. B. Bailey and other staff members of J. D. Woods and Gordon Ltd., Toronto, Canada

This system is based on the complete movements of body members and the following factors are taken into account.

(a) The distance moved during any activity.

During time calculation for distance moved, it is considered by checking whether any muscular control is used. and if used, the amount of muscular control required to stop or slow down the motion, etc.

(b) The visual attention required to carry out the motion of the activity.

The time motion depends on the movement of eyes. Therefore this is taken into consideration. The time taken for the motion with eye movements is considered to be more than that without eye motion.

(c) The degree of precision required in grasping and positioning.

(d) The degree of freedom needed to handle weight or resistance of the components or tools or jigs or fixtures, etc.

(e) Simultaneous motions, for instance the time for reach and move may be affected if performed simultaneously.

All the PMTS techniques are in almost same procedures and have close similarities like the above. Hence, the readers may understand other techniques also.

8.7 MOST

MOST stands for Maynard Operation Sequence Technique. It is yet another technique of work measurement. This was conceptualised around 1967 by Maynard and formalised only in 1975. The basic assumption in this system is that for an overwhelming majority of work, there is a common denominator from which work can be studied through the displacement of the objects. Truly speaking, all the basic units of work are organised for the purpose of accomplishing some useful result by simply moving the objects. In simple words, MOST is a system to measure the work by concentrating on the movement of the objects.

MOST is composed of the following basic sequence models :

- The General Move Sequence (for the spatial movement of an object freely through the air).
- The Controlled Move sequence (for the movement of an object when it remains in contact with a surface attached to another object during movement).
- The Tool Use Sequence (for the use of common hand tools).

In contrast to Methods Time Measurement, PMTS, etc. the primary work units are no longer basic motions, but fundamental activities (collections of basic motions) dealing with moving objects.

SAQ 6

(a) What do you understand by PMTS? What is its importance in time study?

(b) Explain the Work Factor System and its significance in time study.

(c) Explain Method-Time Measurement technique. Give its few applications.

(d) Write short notes on the following :

(i) BMTS

(ii) MOST

8.8 WORK SAMPLING

When you want to purchase a bag of rice or wheat, you check the desired features by taking a sample. A housewife checks whether the rice is cooked by checking one or two grains. A doctor checks one or two drops of blood only to know Complete Blood Picture (CBP). A civil engineer decides the strength of the bricks by breaking one or two bricks to know the force required to break. The performance of a group of bombs is estimated by testing on a sample. Thus, we can notice here that the sampling technique is a powerful tool to know the behaviour of a group or individual particularly, when it is not possible or not feasible or costly to conduct 100% inspection. Why not with the work study? Yes, the answer of this question is nothing but called work sampling or activity sampling. Ratio Delay Analysis. It was first devised by L. H. C. Tippet in 1934 to apply in British Textile Industry. Later Morrow developed with several investigations. The studies through work sampling yielded results very close to that of all day stopwatch time study in most of the cases and hence got popularity by the virtue of its reduced work of the observer. And it is also to be noted that the time study is not economical in the case of long and/or irregular work cycles for which the work sampling is the only alternative.

8.8.1 Objectives

The main objectives of the work sampling are :

- to measure the fair day's work. In other words, it is to measure the activities and delays that a man is working and the percentage that he is not working.
- To establish the time standards for a given job at a certain conditions of work.

8.8.2 Procedure

The following steps are adopted for carrying out work sampling :

(a) State the objective and define by describing each element to be measured.

(b) Get the approval of the foreman and obtain the agreement of co-operation from the workers on whom the study is to be conducted by making them understood the importance.

(c) Set desired accuracy of the final results in the form of percentage or standard error.

(d) Set the confidence level.

(e) On the basis of past experience, estimate (preliminary) the percentage occurrence of the activity or delay to be measured for one day.

(f) Design the study. This includes –

   (i) Designing the Number of Observations to be made.

   (ii) Number of Observers needed for the study.

   (iii) Days or shifts required for the study.

   (iv) Planning the visits and the routes.

   (v) Form of observation.

(g) Make observations and record the data in appropriate form.

(h) Summarize the obtained data at the end of each day.

(i) Check the accuracy/precision at the end of the study.

(j) Prepare a final report with the results and recommendations.

From the above steps. it is very clear that the observers need to observe whether the operator is on the work or delay or idle or not working, etc. with which it is estimated the percentage of working or not working on any normal day. Thus, this study uses sampling theory of statistics and all the rules and conditions will hold good. Therefore, "sufficiency" of number of observations and the characteristics of the samples will play a vital role in the study. It is not an out of place to recall these required characteristics here.

The sample should be :

(a) Representative

(b) Unbiased

(c) Repetitive

(d) Accurate

(e) Efficient

(f) Sufficient

Based on the above characteristics, the sample will be determined at any confidence level (significance level), which is usually chosen at 95% confidence (5% significance) or 99% confidence (1% significance). [A 95% confidence level means that the probability of random observations will represent the facts 95% of the time and 5% of the time they may not.]

The standard formulae used are given below and it is demonstrated through a few numerical problems.

- 1 σ limits represent a confidence level of 68%
- 2 σ limits represent a confidence level of 95%
- 3 σ limits represent a confidence level of 99%

$$S \, . \, P = K \sqrt{\left[\frac{p\,(1-p)}{N}\right]}$$

where, K = 1, 2 or 3 σ confidence level,

N = Sample size or total number of observations,

S = Desired relative accuracy, and

P = Probability or percentage accuracy of an activity or delay as expected in Centimal, e.g. 25% = 0.25.

Example 8.8

Calculate the number of observations for an accuracy of 5% and confidence level of 95% if the probability of the worker in idle is 0.3.

Solution

$$S = \pm\, 5\% = \pm\, 0.05$$

$$P = 0.3$$

$$S \, . \, P = \sqrt{\left[\frac{p\,(1-p}{N}\right]}$$

$$0.05 \times 0.3 = 2\sqrt{\left[\frac{0.3\,(1-0.3}{N}\right]}$$

$$N = 4 \times 0.3 \times \frac{0.7}{(0.015)^2} = 3733.33 \approx 3734$$

SAQ 7

(a) Calculate the number of observations for an accuracy of 5% confidence level of 95% if $P = 0.25$.

(b) Check whether the number of observations is sufficient for an accuracy of 5% confidence level of 95% if 3000 machines are working out of 4000.

8.8.3 Number of Cycles to be Timed

Due to variation of time to perform each element and due to various variations in human behaviours, locations, tools, materials, nature, texture, observational errors, etc. a sufficiently more number of observations are to be taken by repeated experimentation. The sufficiency of observations often depends on the observer's judgement, but in some cases it is fixed by the company policy or by an agreement between the company and trade unions or worker group. However, the satisfactory number decided by the statistical methods based on sampling theory will be more scientific and logical. We use the following formula derived from the sampling (work sampling) theory to find the sufficient number of readings.

$$\text{No. of readings } (N) = \left(\frac{40\sqrt{n \sum X_i^2 - (\sum X_i)^2}}{\sum X_i} \right)^2$$

where, N = Sufficient number of readings,

n = Number of readings taken, and

X = Mean of all readings.

Summary

The sufficient number of observations is calculated by the formula given below.

$$\text{No. of readings } (N) = \left(\frac{40\sqrt{n \sum X_i^2 - (\sum X_i)^2}}{\sum X_i} \right)^2$$

Example 8.9

For a particular task 15 observations were taken by a time study observer. Check whether the number of observations is sufficient for 5% limit of accuracy and 95% confidence level. Indicate the minimum number of observations required.

Time (x in Minutes)	Frequency (f)
1	2
2	3
3	3
4	4
5	5

Solution

x in Minutes	f	$f.x$	x^2	$f.x^2$
1	2	2	1	2
2	3	6	4	12
3	3	9	9	27
4	4	16	16	64
5	3	15	25	75
	15	48		180

$$\sum f = 15$$

$$\sum f_x = 48$$

$$(\sum f_x)^2 = 2304$$

$$\sum f_x^2 = 180$$

$$\text{No. of readings } (N) = \left(\frac{40 \sqrt{n \sum X_i^2 - (\sum X_i)^2}}{\sum X_i} \right)^2$$

$$\text{No. of readings } (N) = \left[40 \frac{\sqrt{15 \times 180 - 2304}}{48} \right]^2 = 16.55$$

∴ The number of observations to be taken = 17.

As the number of observations taken is 15, two more observations are required to get the desired accuracy (5%) at 95% confidence limits.

SAQ 8

Ten observations were taken by a time study observer for a particular task. Check whether the number of observations is sufficient for 5% limit of accuracy and 95% confidence level. Indicate the minimum number of observations required.

Time	Frequency
0.2	2
0.3	1
0.4	3
0.5	1
0.6	3

Example 8.10

To fix up the standard time of a particular work, 5 operators were kept under observation for 4 days by a sample study group. The performance rating and number of times the workers were found working each day were noted and given below.

Operator No.	Performance Rating	Number of Times Found Working			
		1st Jan 2K (X_1)	2nd Jan 2K (X_2)	3rd Jan 2K (X_3)	4th Jan 2K (X_4)
1	100	5	8	7	10
2	110	10	9	6	8
3	120	10	10	9	11
4	125	9	8	8	7
5	130	10	5	12	7

The total number of observations on each day was 50. The working hours per day is 8 hrs. and the total products produced during these four days are 1200. Calculate Standard time for the job. Assume 10% allowance.

Solution

Day	Total No. of Observations that Operators Found Working	Total No. of Observations that Operators Found Idle
1st January, 2K	44	6
2nd January, 2K	40	10
3rd January, 2K	42	8
4th January, 2K	43	7
Total	169	31

The total number of observations in 4 days = 4 × 50 = 200

The total number of times workers found to be working = 169

The total number of times workers found to idle = 31

$$\text{Percentage idle time} = \frac{31}{200} = 15.5\%$$

$$\text{Percentage working time} = \frac{169}{200} = 84.5\%$$

Total study time

= No. of operators × No. of days × Working hours per day × 60 min.

= 5 × 4 × 8 × 60 = 9600 minutes.

Since performance rate of each operator is different, the average performances will differ and the computations are as follows :

$(5 + 8 + 7 + 10) \times 100 = 3000$

$(10 + 9 + 6 + 8) \times 110 = 3630$

$(10 + 10 + 9 + 11) \times 120 = 4800$

$(9 + 8 + 8 + 7) \times 125 = 4000$

$(10 + 5 + 12 + 7) \times 130 = 4420$

Total = 19850

Total number of times workers found working = 169

$$\text{Average performance rate} = \frac{19850}{169} = 117.5$$

Standard time in minutes per component

= [Total working time in min × (Percent working time/100) × (Average performance rate/100) / Total quantity produced during the observed period] + Allowance Factor.

$$= \left[9600 \times \left(\frac{84.5}{100}\right) \times \frac{\left(\frac{117.5}{100}\right)}{1200} \right] \times \frac{100}{100 - 10}$$

$$= \left[9600 \times \left(\frac{84.5}{100}\right) \times \frac{\left(\frac{117.5}{100}\right)}{1200} \right] \times \frac{100}{100 - 10}$$

SAQ 9

An operator was kept under observation for 10 days. In 250 observations, he was found to be on job for 200 times and idle for 50 times. He produced 200 jobs during the 10 days at a performance rate of 120. If the observation period is 5 hours only per day and 15% allowances are given, find the normal time and standard time.

8.8.4 Applications of Work Sampling

Work sampling can be applied to :

- estimate the machine utilization and resources utilization,
- estimate unavoidable delays in decision making of delay allowances,
- evaluate the time consumed by different activities such as repairs, inspection supervision, etc., and
- find out the standard time for non-repetitive jobs where stopwatch method is not possible or not economic.

8.8.5 Advantages of Work Sampling Over Time Study

(a) Group of operations can be studied in a single analysis, which is not possible, by time study.

(b) It does not need continuous and a long period of observation.

(c) Operations are not kept under risks and strains unlike in stopwatch observations.

(d) Some activities are impractical or costly to study by stopwatch. These can be estimated easily by this method.

(e) Man hours spent by the observers is very less in this simplified technique of evaluation.

(f) Observations are made on different days or weeks in all combinations, thereby reducing the chances that effect on variations due to working efficiency.

(g) Sampling study can be stopped at any time without affecting the results.

(h) Observations can be observed at his convenience.

(i) No other timing devices and equipment such as stopwatch is required.

(j) Clerical work is minimised.

8.8.6 Disadvantages

(a) Not economical to conduct on a single operation or machine.

(b) Not economical to study on machines located over wide areas.

(c) Does not provide breakdown of delays or activities.

(d) The study is based on average group performance and hence the individual variations are not evaluated.

(e) The clarity and understandings between management, foremen, observers and operators may miss and varies with attributes.

(f) Biased opinions may lead to wrong interpretations of results.

(g) Method or technological changes and other changes are not taken into account. If such changes occur between any two observations the results will be misinterpreted.

(h) Accuracy is based on statistics and therefore probablistic while stopwatch studies are deterministic.

(i) Sampling errors may occur which hamper the results.

(j) Workmen behaviour and attitudes may affect the results.

SAQ 9

(a) What do you understand by work sampling? How do you recognise it as a work measurement technique?

(b) Distinguish between time study and work sampling.

(c) Discuss the advantages and limitations of work sampling over time study.

(d) Enumerate the applications of the work sampling technique.

(e) What are the objectives of work sampling? How do they fit in work study?

(f) Explain the role of work sampling and time study in improving the productivity.

Activity 4

Conduct a work sampling programme in your organisation and write down the results. Give your recommendations based on the results.

....

....

....

8.9 SUMMARY

Although desirability of effective method is stressed always and there have been lot of efforts put in this direction, yet, it is very difficult and not always possible/feasible for an industrial engineer that the effective method is developed before the work actually enters the industry. We are well aware of the resistance and barriers put before the managements while introducing new methods and timing them. In this scenario, the task of method improvement in one hand and the target fixation for the job on the other hand, the time study has played a dual role effectively. Though this was originally proposed for creating the systematic work culture through definite task, definite method and definite time which in turn intended to result in improved production (during the period of world wars and industrial revolution), the time study and work measurement techniques have become so popular that they are the only proven tools for an industrial engineer today for improvement of method, fixation of task and time of a job or work or activity and thence the productivity. And the time study is not just confined to method improvement and task and time fixation, but it had spread out its branches in task assessment, wage fixation and wage incentive decisions too. Hats off to F. W. Taylor for his time study.

Time study often called work measurement, was the brainchild of F. W. Taylor. He suggested to split the work into small elements and these elements are to be timed separately. On summing up these elemental times the standard time can be calculated. This unit covered the methodology of the time study and work measurement. The use of stopwatches, calculators, spring balances, tachometers, etc. has been stressed appropriately. A systematic approach established through various equipment is given. The concepts used in work measurement such as performance rating, allowances, PMTS, MOST and work sampling are narrated. Under performance rating various methods, viz. Westinghouse rating, Objective rating, Synthetic rating, Skill and effort rating, Physiological measurements are explained. An effort is made to provide good understanding on allowances to convert the normal time into standard time by dealing with various allowances. A clear picture on PMTS is structured through the techniques such as WFS, MTM, BMTS, etc. A brief description on MOST is also given. The statistical method of work measurement, proposed by L. H. C. Tippet is elaborately described under work sampling.

8.10 KEY WORDS

Work Measurement : Work measurement is the application of techniques designed to establish the time for a qualified worker to carry out a specified job at a defined performance.

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

Monotony : The feeling of an operator in doing the same job repetitively for a long period when he becomes mechanical.

Boredom : A temporary negativity towards working out of the fatigue occurred due to continuous working.

Cycle Time : Time taken to complete the sequential operations in a task or job.

Basic Time : Actual time taken for completion of a job when observed.

Normal Time : Time taken by an operator for completion of job in normal condition, i.e. it is the product of the basic time and rating factor. Normal Time = Observed Time × Rating Factor.

Standard Time : Time taken to complete a task or job at standard conditions operator, i.e. sum of normal time and allowances. Standard Time = Normal Time + Allowance.

Element : An element is defined as "a distinct part of the specified job selected for convenience of observation, measurement and analysis".

Man Controlled Elements	:	The elements controllable manually such as handling time.
Machine Controlled Elements	:	The elements, which are under the control of machine like machining time.
Effective Time Element	:	It is the productive element that occurs during performing the job.
Ineffective Time Elements	:	It is the time element occurring during an activity, which is non-productive.
The Constant Elements	:	These are independent of size, shape, weight, etc. of work.
Variable Elements	:	These are dependent of size, shape, weight, etc. of work.
Performance Rating	:	The society of Advancement of Management National Committee defines the performance rating as "the process during which the time study engineer compares the performance of the operator under observation with the observer's own concept of proper (normal) performance". It can also be considered as the efficiency of the worker. The performance rating or Efficiency = (Observed Performance/Normal Performance) $\times$ 100.
Westinghouse System of Rating	:	The system of rating based on four factors Skill, Effort, Conditions and Consistency.
Synthetic Rating	:	The system of rating, introduced by Morrow is based on standardised values taken from tables of "Predetermined Motion Time Values" or 'PMTS Values'.
Objective Rating	:	It was proposed by M.E. Mundel and is carried out by comparing with pace rating first to find the base time and appraised by a secondary adjustment or job difficulty factor to find the normal time.
Skill and Effort Rating	:	This system, also known as Bedaux system, is based on evaluation of the rate of work in terms of Bedaux points (B's) composing of work component and relaxation component.
Physiological Evaluation of Performance Level	:	It is a system of rating the physical work by the amount of oxygen consumed.
Interference Allowance	:	This is provided on a job where the operator is working on several machines to compensate the machine interference due to settings, positioning, etc.
Relaxation Allowance	:	The time allowance given to the employee to recover from the fatigue and to attend his personal needs developed by the physiological and psychological factors.
Process Allowance	:	The allowance of time given to the operator as is demanded by the process itself.

Contingency Allowance	:	It is a percent of basic time (less than 5%) recommended by the observer and is a small allowance to meet legitimate expected items of work or delays.
Special Allowance	:	These are the allowances such as policy allowances and others given by the company on special circumstances and occasional.
Predetermined Motion Time Standards (PMTS)	:	The time values of the work elements, established accurately to make use of these without any further time study, whenever such element occurs.
Work Factor System (WFS)	:	It is the system of PMTS by an assumption that the time required to perform a task is affected by four factors, viz. Body member, Distance moved, Manual control required and Weight or resistance.
Method Time Measurement (MTM)	:	"The procedure, which analyses any manual operation or method into the basic motions required to perform it and assigns to each motion a Predetermined Motion Time Standard (PMTS), which is determined by the nature of motion under which it is made".
Basic Motion Time Study (BMTS)	:	It is the PMTS system based on the complete movements of body members, the distance moved during an activity, visual attention required, the degree of freedom needed to handle weight or resistance and simultaneous motions.
TMU	:	Time-Motion Unit (TMU) is the unit of measuring time standards in MTM system. 1 TMU = 0.0006 minutes.
MOST	:	MOST, the Maynard Operation Sequence Technique, study of work through the displacement of the objects. MOST is composed of General Move Sequence, Controlled Move Sequence and Tool Use Sequence.
Work Sampling	:	The technique of estimating and evaluating the standard time of an activity or a group of activities or a work of longer cycle by making use of statistical sampling theory in which the presence of worker on work is taken into account to find work delays and working period.

8.11 ANSWERS TO SAQs

SAQ 1

(a) Normal times 0.6, 0.8, 1.56 and 1.35 and standard times 0.63, 0.84, 1.638 and 1.4175 min.

(e) Normal Time is 1.6 min, Allowance is 10%.

SAQ 2

(a) OT = 1 min; NT = 1 min: $ST = NT\left(\frac{100}{100 - \text{allowances}}\right)$

(b) 2.26

(c) 2.26

(d) 0.4165

SAQ 3

(a) 0.43 minute

(b) 30%

SAQ 4

0.5 B

SAQ 7

(a) 4800

(b) Insufficient, some more are required; no. of observations required = 4800.

SAQ 8

14 observations (Four more are required).

SAQ 9

Normal Time = 1.44 minutes

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

STATISTICAL PROCESS CONTROL

STATISTICAL PROCESS CONTROL (SPC)

•Is the application of Statistical Methods to monitor and control a process to ensure that it operates at its full potential to produce conforming product.

OR

•Is an analytical decision making tool which allows you to see when a process is working correctly and when it is not.

•Variation is present in any process, deciding when the variation is natural and when it needs correction is the key to quality control.

HISTORY

•Was Pioneered By Walter .A. Shewhart In The Early 1920s.

•W. Edwards Deming Later Applied SPC Methods In The US During World war II, Successfully Improved Quality In The Manufacture Of Munitions And Other Strategically Important Products.

•Deming introduced SPC Methods to Japanese Industry After The War Had Ended.

•Resulted high quality of Japanese products.

•Shewhart Created The Basis For The Control Chart And The Concept Of A State Of Statistical Control By Carefully Designed Experiments.

- Concluded That While Every Process Displays Variation, Some Processes Display Controlled Variation That Is Natural To The Process (Common Causes Of Variation), While Others Display Uncontrolled Variation That Is Not Present In The Process Causal System At All Times (Special Causes Of Variation).
- In 1988, The Software Engineering Institute Introduced The Notion That SPC Can Be Usefully Applied To Non-manufacturing Processes

TRADITIONAL METHODS VS STATISTICAL PROCESS CONTROL

- The quality of the finished article was traditionally achieved through post-manufacturing inspection of the product; accepting or rejecting each article (or samples from a production lot) based on how well it met its design specifications

- SPC uses Statistical tools to observe the performance of the production process in order to predict significant deviations that may later result in rejected product.

TYPES OF VARIATION

Two kinds of variation occur in all manufacturing processes

1. Natural or Common Cause Variation
   - consists of the variation inherent in the process as it is designed.
   - may include variations in temperature, properties of raw materials, strength of an electrical current etc.

2. Special Cause Variation or Assignable-cause Variation

   With sufficient investigation, a specific cause, such as abnormal raw material or incorrect set-up parameters, can be found for special cause variations.

‘In Control’ and ‘Out Of Control’

❖ **<u>Process is said to be ‘in control’ and stable</u>**

If common cause is the only type of variation that exists in the process

It is also predictable within set limits i.e. the probability of any future outcome falling within the limits can be stated approximately.

❖ **<u>Process is said to be ‘out of control’ and unstable</u>**

Special cause variation exists within the process

Statistical process control -broadly broken down into 3 sets of activities

1. Understanding the process

2. Understanding the causes of variation

3. Elimination of the sources of special cause variation.

Understanding the process

- Process is typically mapped out and the process is monitored using control charts.

Understanding the causes of variation

- Control charts are used to identify variation that may be due to special causes, and to free the user from concern over variation due to common causes.
- It is a continuous, ongoing activity.
- When a process is stable and does not trigger any of the detection rules for a control chart, a process capability analysis may also be performed to predict the ability of the current process to produce conforming product in the future.

- When excessive variation is identified by the control chart detection rules, or the process capability is found lacking, additional effort is exerted to determine causes of that variance.

- The tools used include

  - **Ishikawa diagrams**
  - **Designed experiments**
  - **Pareto charts**

- Designed experiments are critical -only means of objectively quantifying the relative importance of the many potential causes of variation.

Elimination of the sources of special cause variation

•Once the causes of variation have been quantified, effort is spent in eliminating those causes that are both statistically and practically significant.

•includes development of standard work, error-proofing and training.

•Additional process changes may be required to reduce variation or align the process with the desired target, especially if there is a problem with process capability.

ADVANTAGES OF SPC

- Reduces waste

- Lead to a reduction in the time required to produce the product or service from end to end
due to a diminished likelihood that the final product will have to be reworked, identify bottlenecks, wait times, and other sources of delays within the process.

- A distinct advantage over other quality methods, such as inspection - its emphasis on early detection and prevention of problems

- Cost reduction

- Customer satisfaction

SPC CHARTS

•One method of identifying the type of variation present.

•Statistical Process Control (SPC) Charts are essentially:

❖Simple graphical tools that enable process performance monitoring.

❖Designed to identify which type of variation exists within the process.

❖Designed to highlight areas that may require further investigation.

❖Easy to construct and interpret.

•2 most popular SPC tools

❖ **Run Chart**

❖ **Control Chart**

•SPC charts can be applied to both dynamic processes and static processes.

Dynamic Processes

○A process that is observed across time is known as a dynamic process.

○An SPC chart for a dynamic process - „time-series‟ or a „longitudinal‟ SPC chart.

Static Processes

○A process that is observed at a particular point in time is known as a static process.

○An SPC chart for a static process is often referred to as a „cross sectional‟ SPC chart.

Control charts

- Show the variation in a measurement during the time period that the process is observed.

- Monitor processes to show how the process is performing and how the process and capabilities are affected by changes to the process. This information is then used to make quality improvements.

- A time ordered sequence of data, with a centre line calculated by the mean.

- Used to determine the capability of the process.

- Help to identify special or assignable causes for factors that impede peak performance.

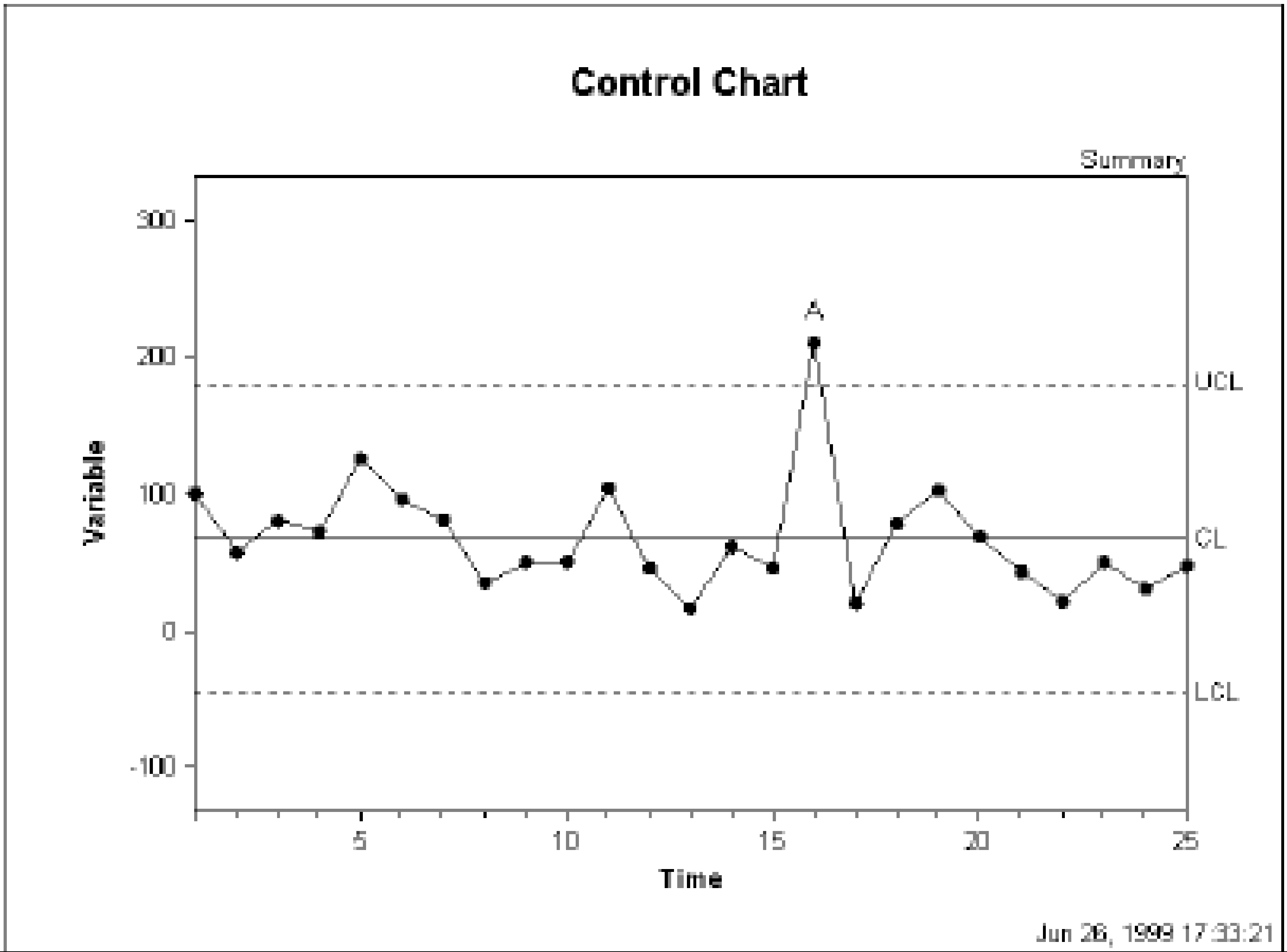
Control charts have four key features:

1) **Data Points:**
   Either averages of subgroup measurements or individual measurements plotted on the x/y axis and joined by a line. Time is always on the x-axis.

2) **The Average or Center Line**
   The average or mean of the data points and is drawn across the middle section of the graph, usually as a heavy or solid line.

3) **The Upper Control Limit (UCL)**
   Drawn above the centerline and annotated as "UCL". This is often called the “+ 3 sigma” line.

4) **The Lower Control Limit (LCL)**
   Drawn below the centerline and annotated as "LCL". This is called the “- 3 sigma” line.


Control Chart
Summary
300
200
100
0
-100
Variable
A
UCL
CL
LCL
5
10
15
20
25
Time
Jun 26, 1999 17:33:21

- Control limits define the zone where the observed data for a stable and consistent process occurs virtually all of the time (99.7%).

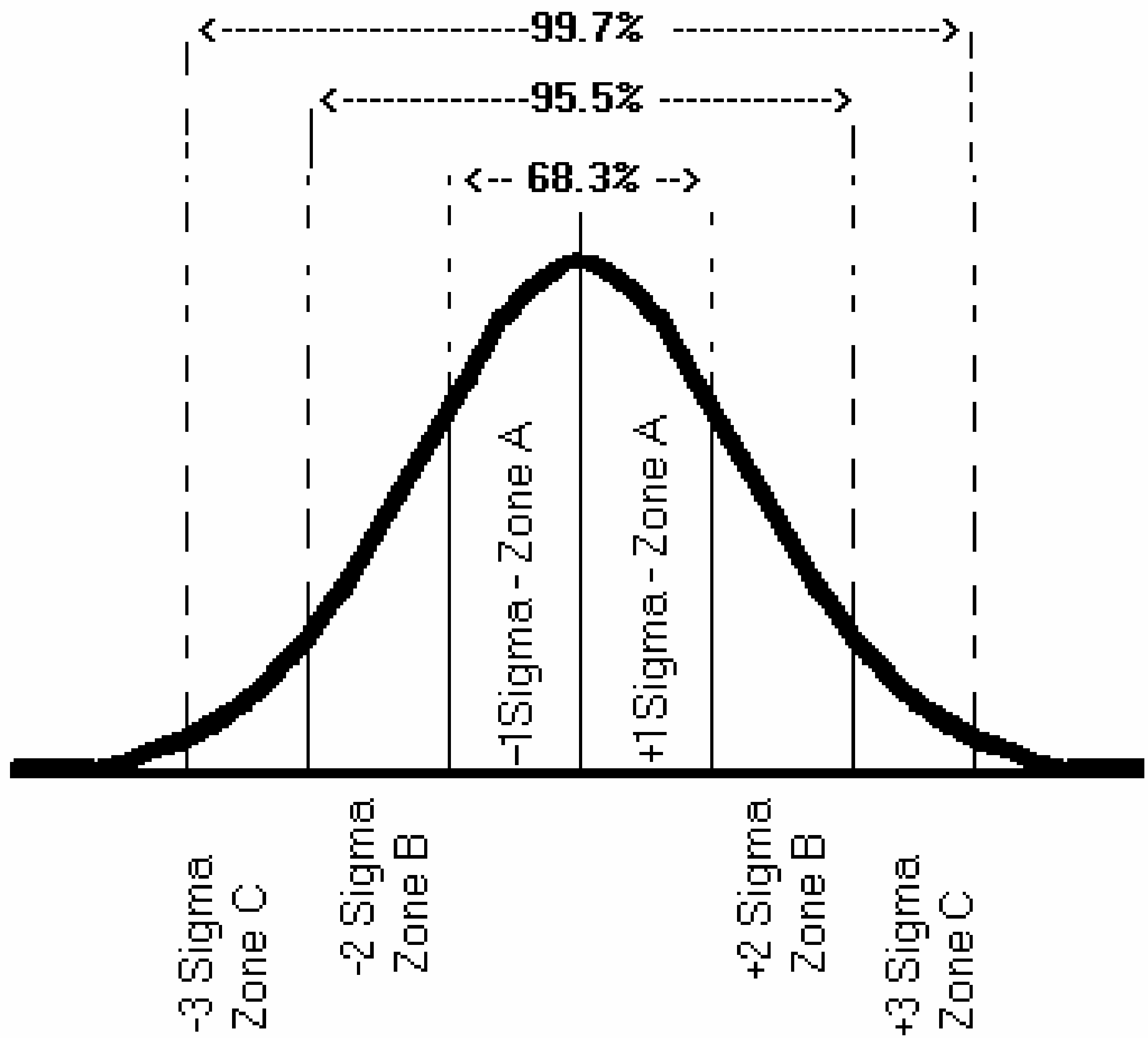
- Any fluctuations within these limits come from common causes inherent to the system, such as choice of equipment, scheduled maintenance or the precision of the operation that results from the design.

- An outcome beyond the control limits results from a *special cause.*

- The automatic control limits have been set at 3-sigma limits.

•The area between each control limit and the centerline is divided into thirds.

1) Zone A - "1-sigma zone“
2) Zone B - "2-sigma zone"
3) Zone C - " 3-sigma zone “



99.7%
95.5%
68.3%
-1Sigma - Zone A
+1Sigma - Zone A
-3 Sigma Zone C
-2 Sigma Zone B
+2 Sigma Zone B
+3 Sigma Zone C

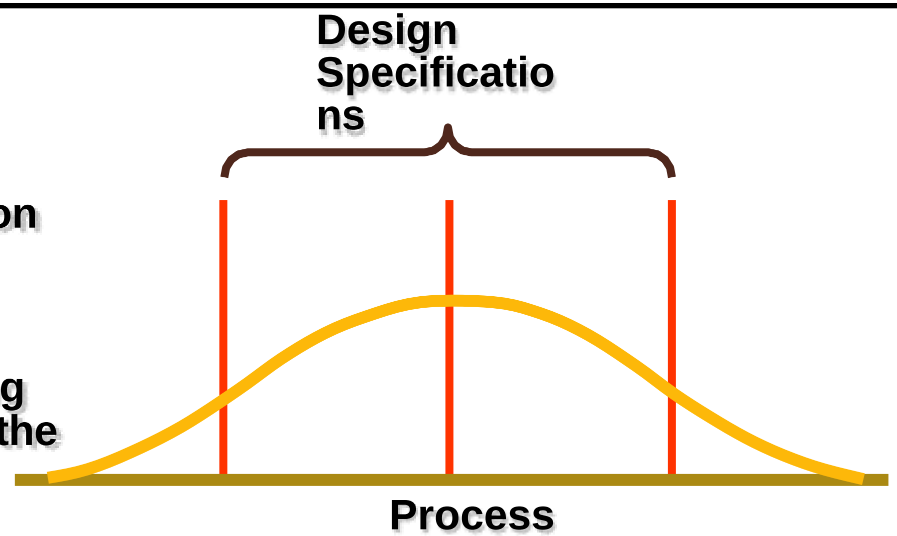
PROCESS CAPABILITY ANALYSIS

- Examines
  - whether the process is capable of producing products which conforms to specifications
  - range of natural variability in a process what we measure with control charts

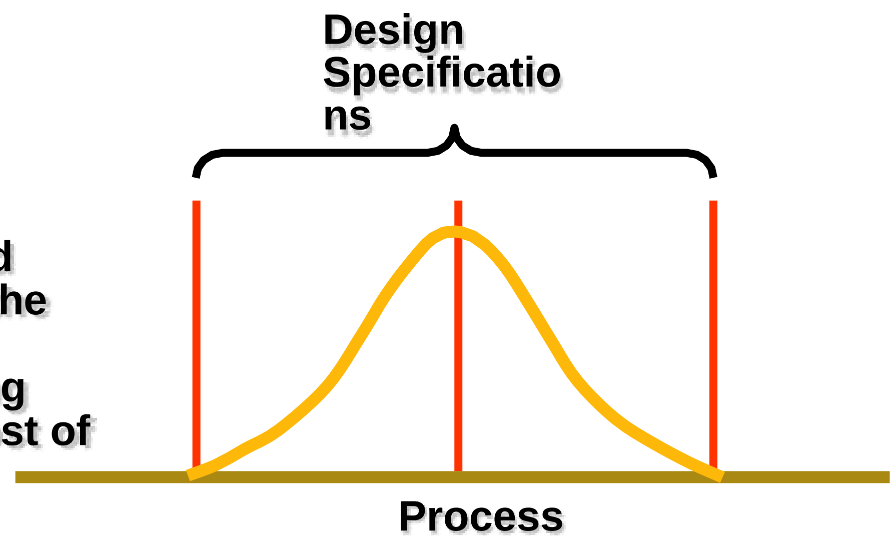
- Process capability studies distinguish between conformance to **control limits** and conformance to **specification limits** (also called **tolerance limits**)
  - if the process mean is in control, then virtually all points will remain within control limits
  - staying within control limits does not necessarily mean that specification limits are satisfied
  - specification limits are usually dictated by customers

Process Capability analysis cont.

(a) Natural variation exceeds design specifications; process is not capable of meeting specifications all the time.

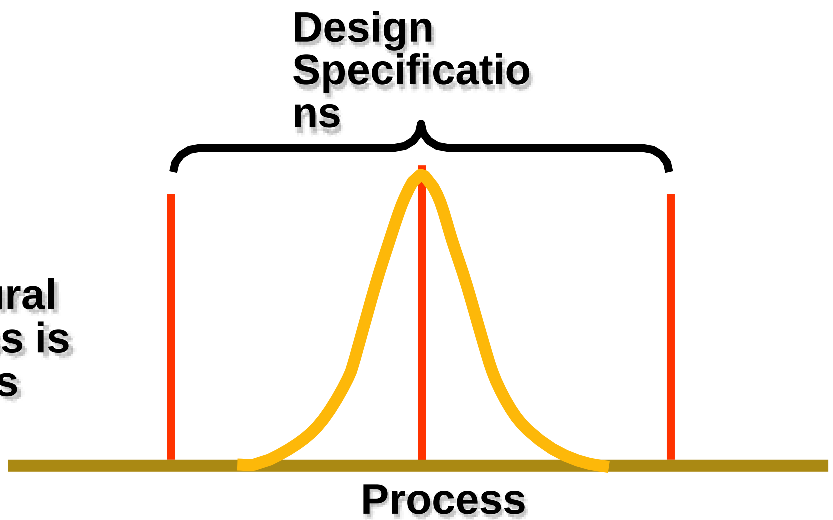


(b) Design specifications and natural variation the same; process is capable of meeting specifications most of the time.

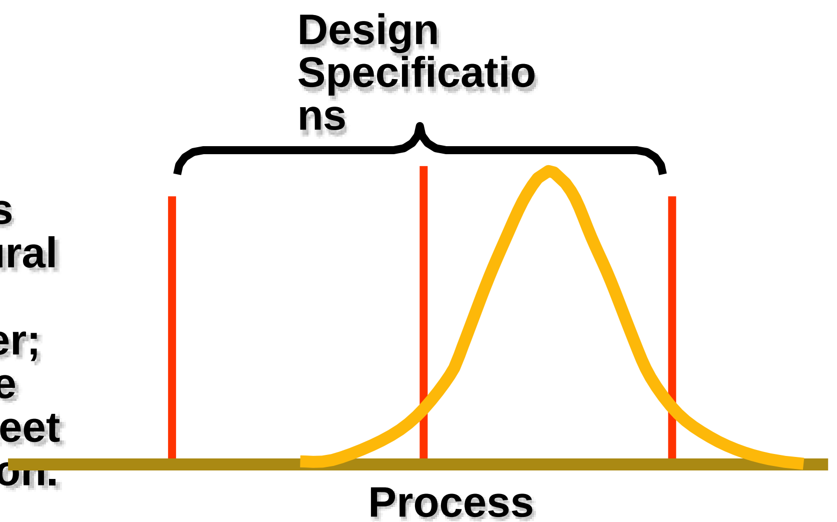


Process Capability (cont.)

(c) Design specifications greater than natural variation; process is capable of always conforming to specifications.



(d) Specifications greater than natural variation, but process off center; capable but some output will not meet upper specification.



MAN-MACHINE SYSTEM

- Human factors are a system concerned with the relationship among human beings, work place or work environment and machines. All man-machine systems are produced with some objective in view.
- This objective is always well defined and the system is designed so as achieve the objective as successfully as possible. In view of this the operational functions of both the components and constituents i.e. man and machine should be clearly defined.

Characteristics of Man-machine System

(1) The man-machine system consists of the man, the machine and system environment.
(2) It is essentially artificial by nature and is specifically developed to fulfill some purpose or specific aim.
(3) It has specific inputs and outputs which are appropriately balanced.
(4) It is variable in size and complexity and is dynamic in performance.
(5) Subsystems of man machine system interact with and effects the other parts.
(6) The man-machine system becomes more efficient when inputs and out puts are adequately balanced.
(7) Environmental factors or system environment effects system performance.

MACHINE - AS A COMPONENT OF MAN-MACHINE SYSTEM

- Machine receives instructions from the man and it carries them out and usually indicates its progress to the man by a display of information.

- Therefore as many ergonomic measures as possible should be introduced at the design stage of a building, appliance or machine, or when equipment is being installed

The function usually best to allocate to a machine,

- For computing, differentiation, integration,
- When Response is required at great speed,
- Short-term information storage (memory), and
- For simple yeslno decision.

A machine user should incorporate ergonomic standards in the clauses of his contract with the machine manufacturer.

MAN - AS A COMPONENT OF MAN-MACHINE SYSTEM

- Man plays a vital role in the success of man-machine system.

- The sequence of events generated from the receipt of the external stimulus to the completion of a response is very complicated one.

- It involves the transduction of the external or internal stimuli, the perception of the signals and their meaning, the making ofjudgment (mental process), Man-Machine Systems the placing of information into temporary or permanent storage (memory) and recall as and when necessary, finally leading to a decision making

FUNCTIONS OF MAN ELEMENT IN MAN-MACHINE SYSTEM

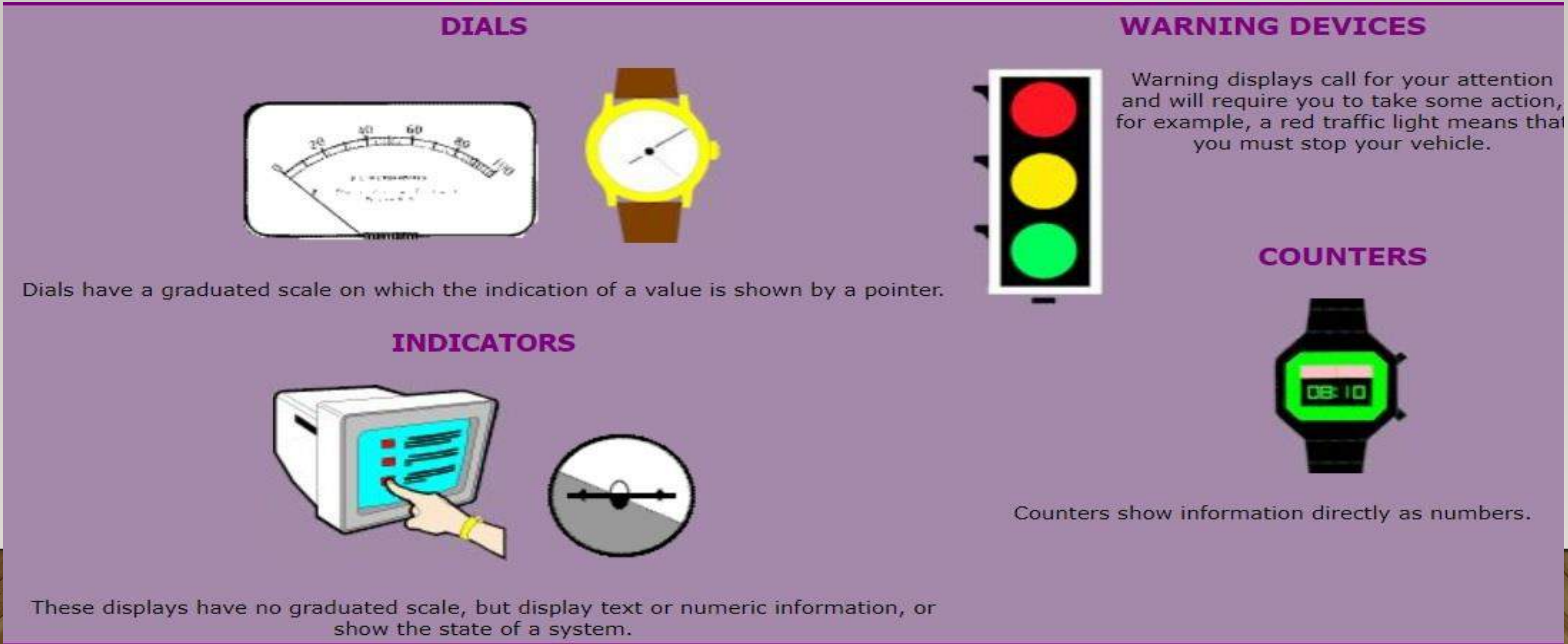
- As a Sensing Device
- As an Amplifier, Flexibility, Switching Device
- Long Term Storage
- Making Judgment and Predictions

DISPLAYS

Displays will generally be effective if they have:

- Good ***visibility*** - you can easily and clearly see the displays. To attract attention visually, the display must be within your field of vision and should flash or change in some other way. Humans are very good at detecting movement.
- Good ***comprehension*** – you can make the correct decisions and control actions with minimum effort and delay, and with as few errors as possible, because you have understood the displayed information.
- Good ***compatibility*** - the display can be used easily with others and you are not confused by any different types used. It can easily be seen and understood in the space and lighting in which it is used. The movement and layout of displays matches those of their controls.

TYPES OF DISPLAYDISPLAYS CAN BE CLASSIFIED ACCORDING TO THEIR PHYSICAL CHARACTERISTICS (WHAT THEY LOOK LIKE), OR ACCORDING TO THE TYPE OF INFORMATION THAT THEY PROVIDE (WHAT THEY ARE TELLING YOU).



CLASSIFICATION ACCORDING TO TYPE OF INFORMATION DISPLAYED:

- **QUANTITATIVE DISPLAYS**

Quantitative displays show exact information. Digital quantitative displays present information directly as numbers, for example, the clock on your computer. Analogue quantitative displays can also be used where a length or angle represents the information, for example, a thermometer where the length of mercury or alcohol represents the temperature. The use of a particular quantitative display depends on the kind of information that is required. If you need a precise reading, then digital indicators are most easily read.

QUALITATIVE DISPLAYS

- Qualitative displays give information about particular states, for example, hot or cold, alarm or no alarm. These displays can provide information about rate of change or direction of deviation from a desired value. These displays may include indicators and warning devices. They can be used in circumstances where you only need to know that a certain condition exists. The specific value is not needed, although that may be conveyed to you by other, quantitative visual displays.
- Check-reading displays are a specific type of qualitative display in which you determine whether the value of a continuously changing variable is normal, or within an acceptably normal range, for example, car fuel gauges and tyre pressure gauges. Check-reading displays should have clearly distinguishable characteristics to identify the neutral or normal satisfactory condition, or the undesirable condition; perhaps green marking for an 'OK' level and red for 'out-of-limits'.

REPRESENTATIONAL DISPLAYS

- Representational displays should aim at schematic representation of information (keep it simple) rather than a complete representation or the actual representation.
- The well-known London Underground map is an example of representing the geographic situation by a stylised and clearer design. The exact geographic inter-relationships of stations are replaced by a colour-coded series of lines which convey the structural layout of the system and make it easier for you to plan your route.

ALPHANUMERIC AND RELATED DISPLAYS

- The effectiveness of such displays depends upon various factors like typography, content, selection of words, color, background, contrast, illumination, and writing styles. The typography of alphanumeric information includes stroke width, aspect ratio, font type, font size, spacing of characters, spacing between lines, margins, color, etc. The communication of message by such displays depends upon visibility, legibility, and readability