ANNAMACHARYA UNIVERSITY

EXCELLENCE IN EDUCATION; SERVICE TO SOCIETY
(ESTD UNDER AP PRIVATE UNIVERSITIES (ESTABLISHMENT AND REGULATION) ACT, 2016)
RAJAMPET-516126:A.P; INDIA

DEPARTMENT OF MECHANICAL ENGINEERING

LECTURE NOTES

Industrial Management
[24AMEC41T]

Prepared by
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ANNAMACHARYA UNIVERSITY

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DEPARTMENT OF MECHANICAL ENGINEERING

Title of the Course: Industrial Management
Category: HSMC
Semester: IV Semester
Course Code: 24AMEC41T
Branch/es: Mechanical Engineering

Lecture Hours	Tutorial Hours	Practice Hours	Credits
3	0	0	3

Course Objectives:

1. To introduce the scope and role of industrial engineering and the techniques for optimal design of layouts
2. To illustrate how work study is used to improve productivity and project management techniques
3. To explain TQM and quality control techniques.
4. To introduce financial and marketing management aspects.
5. To discuss human resource management and value analysis

Course Outcomes:

At the end of the course, the student will be able to

1. Describe the principles and functions of management & Plant layouts.
2. Apply work study methods and project management concepts at Industrial level.
3. Analyze data using control charts to monitor, improve quality and inventory control.
4. Describe various sources of finance, marketing and their implications.
5. Describe human resource management methods.

Unit 1 Introduction & Plant Layout 08

Introduction: Definition of industrial engineering (I.E), development, applications, role of an industrial engineer, differences between production management and industrial engineering, productivity measurement. concepts of management, importance, functions of management, scientific management, Taylor's principles, Fayol's principles of management.

PLANT LAYOUT: Factors governing plant location, types of production, types of layouts, advantages and disadvantages of process layout and product layout, Fixed position layout, applications.

Unit 2 Work Study & Project Management 07

Work Study: Importance, applications, work study, method study and time study(elementary treatment), work sampling, PMTS, micro-motion study, rating techniques, MTM, flow process charts, string diagrams and Therbligs.

Project Management: Network Analysis, Programme Evaluation and Review Technique (PERT), Critical Path Method (CPM), Identifying critical path, Probability of Completing the project within given time, Project Cost Analysis, Project Crashing (simple problems).

Unit 3 Statistical Quality Control & Total Quality Management 07

Statistical Quality Control: Quality control, and its importance, SQC, attribute sampling inspection with single and double sampling, Control charts X and R charts and their applications, simple numerical examples. Inventory, types of Inventories, Inventory control, EOQ, Inventory control techniques, ABC, VED, FSN, SOS, GOLF Analysis.

Total Quality Management: Elements of TQM – Continuous Improvement zero defect concept, quality circles, implementation, applications, ISO quality systems. Six Sigma–definition, basic concepts

Unit 4 Financial Management & Marketing **07**

Financial Management: Scope and nature of financial management, Sources of finance, Ratio analysis, Management of working capital, Nature of Investment Decisions – Investment Evaluation criteria- NPV, IRR, PI, Payback Period, and ARR, numerical problems.

Marketing: Functions of Marketing, Marketing Mix, and Marketing Strategies based on Product Life Cycle, Channels of distribution.

Unit 5 Human Resource Management & Value Analysis **06**

Human Resource Management: Concept of human resource management, personnel management and industrial relations, functions of personnel management, Job-evaluation, its importance and types, merit rating, quantitative methods, wage incentive plans, and types.

Value Analysis: Value engineering, implementation procedure, enterprise resource planning and supply chain management

Prescribed Textbooks:

1. O.P Khanna, Industrial Engineering and Management, Dhanpat Rai Publications (P) Ltd, 2018
2. Martand Telsang, Industrial Engineering and Production Management, S.Chand & Company Ltd. New Delhi, 2006

Reference Books:

1. M.Mahajan Industrial Engineering and Production Management, Dhanpat Rai & Co (P) Ltd, 2000
2. Bhattacharya DK, Industrial Management, S.Chand, publishers, 2010
3. J.G Monks, Operations Management, 3/e, McGraw Hill Publishers1987
4. T.R. Banga, S.C.Sharma, N. K. Agarwal, Industrial Engineering and Management Science, Khanna Publishers, 2008
5. Koontz O'Donnell, Principles of Management, 4/e, McGraw Hill Publishers, 1968
6. R.C.Gupta, Statistical Quality Control, Khanna Publishers, 1998

Web Resources:

1. https://www.youtube.com/watch?v=ckiMUG2imuM
2. https://youtu.be/4vq0FKWYud8
3. https://youtu.be/zdLWc9zs77Q
4. https://youtu.be/-TDh-5n90vk
5. https://youtu.be/BWbnKgFNcKg
6. https://youtu.be/_iWJzSp_foE

CO-PO Mapping:

Course Outcomes	Engineering Knowledge	Problem Analysis	Design/Development of solutions	Conduct investigations of complex problems	Engineering Tool usage	The Engineer and The World	Ethics	Individual and Collaborative team work	Communication	Project management and finance	Life-long learning	PSO1	PSO2
24AMEC41T.1	2	2	2	2	-	-	-	-	-	-	-	2	2
24AMEC41T.2	3	2	2	2	-	-	-	-	-	-	-	1	1
24AMEC41T.3	2	2	2	2	-	-	-	-	-	-	-	1	1
24AMEC41T.4	3	2	2	2	-	-	-	-	-	-	-	2	2
24AMEC41T.5	2	2	2	2	-	-	-	-	-	-	-	2	2

UNIT I

INTRODUCTION TO MANAGEMENT

INTRODUCTION

In the present context, managing has become one of the most important areas of human activity because of increasing role of large and complex organisations in the society. Because of their increasing role, the organisations have attracted the attention of both practitioners and academicians to find out the solutions for business problems.

Concept

Defining the term management precisely is not so simple because the term management is used in a variety of ways. Being a new discipline, it has drawn concepts and principles from a number of disciplines such as economics, sociology, psychology, anthropology, and statistics and so on.

Each group of contributors has treated management differently. For example, economists have treated management as a factor of production; sociologists have treated it as a class or group of persons; practitioners have treated it as a process comprising different activities.

DEFINITION

—Management is the art of getting things done through and with people in formally organized groups‖ **--- Koontz**

—Management is the art of knowing what you want to do and then seeing that it is done in the best and cheapest way‖ **–F.W. Taylor**

—Management is the art of securing maximum results with minimum effort so as to secure maximum prosperity and happiness for both employer and employee and give the public the best possible service‖ **--- John Mee.**

—Management is the accomplishment of results through the efforts of other people‖ **- - Lawrence**

—Management is simply the process of decision making and control over the action of human beings for the expressed purpose of attaining pre-determined goals‖ – **Stanley V.**
Management is a process involving planning, organizing, staffing, directing and controlling human efforts to achieve stated objectives in an organization. ‖

From the above definitions, the following **features** are identified: -

1) **Organised Activities**: Management is a process of organizedactivities. Without organized activities, two groups of people cannot be involved in the

performance of activities. Where a group of people are involved in working towards a common objective, management comes into existence.

2) **Existence of objectives**: The existence of objectives is a basiccriterion of e very human organization because all organizations are deliberate and purposive creation and, therefore, they should have some objectives. Without objectives, it becomes difficult to define the direction where organized group of activities would lead to.
3) **Relationship among resources**: Organised activities meant toachieve common goals are brought about to establish certain relationships about the available resources. Resources include money, machine, material, men and methods. All these resources are made available to those who manage the organization. Managers apply knowledge, experience, principles for getting the desired results. Thus, the essence of management is integration of various organisational resources.
4) **Working with and through people**: Management involves workingwith people and getting organisational objectives achieved through them. The idea of working through people is interpreted in terms of assigning and reassigning of activities to subordinates.
5) **Decision Making**: Management process involves decision making atvarious levels for getting things done through people. Decision making basically involves selecting the most appropriate alternative out of the several. If there is only one alternative, there is no question of decision making.

Nature of Management: - The study and application of managementtechniques in managing the affairs of the organization have changed its nature over a period of time. The following points will describe the nature of management

1) **Multidisciplinary**: Management has been developed as a separatediscipline, but it draws knowledge and concepts from various disciplines like psychology, sociology, anthropology, economics, statistics, operations research etc.,. Management integrates the idea
nd concepts taken from these disciplines and presents newer concepts which can be put into practice for managing the organisations
2) **Dynamic nature of Principles**: Principle is a fundamental truthwhich establishes cause and effect relationships of a function. Based on integration and supported by practical evidences, management has framed certain principles. However, these principles are flexible in nature and change with the changes in the environment in which an organization exists.
3) **Relative, Not absolute Principles**: Management principles arerelative, not absolute, and they should be applied according to the need of the organization. Each organization may be different from others. The difference may exist because of time, place, socio-cultural factors, etc.,.
4) **Management: Science or Art**: There is a controversy whethermanagement is science or art.
An **art** is personal skill of business affairs. Art is characterized by practical knowledge, personal creativity and skill. The more one practices an art, the more professional one becomes. Management can be considered as an art because it satisfies all these criterion of an art. A **science** is a systematized body of knowledge of facts. It can establish cause-and-effect relationships

INTRODUCTION TO MANAGEMENT

Introduction to Management:

When human being started group activities for the attainment of same common objectives whenever a group is formed and a group activity is organized to achieve certain common objectives management is needed to direct, co-ordinate and integrate the individual activities of a group and secure teams work to accomplish organizational objectives. The objectives of all business are attained by utilizing the scare resources like men, materials, machines, money etc.

In process of management, a manage uses human skills, material resources and scientific methods to perform all the activities leading to the achievement of goods.

Companies of same industry are being affected by the same environmental factors. Some companies attract a number of customers while some companies repel them. The management is different from one company to other company in working conditions and also differs in their activities.

The management makes remarkable differences between the companies regarding their performance in terms of productivity, products, sales, profitability, service to the customer, employee welfare etc. So management plays a vital role in deciding the destiny of business as well as non business organizations. This is called Management.

The management is a science or art. So there is a dilemma regarding the nature of management, whether it belongs to the category of science of Arts. Specification as nature of management is necessary to determine the specification of nature of management is necessary to determine the process of learning of management. Hence, in order to find out the nature of management, fundamentally, it is required to know what is science or an art.

Definition: "Management is knowing exactly what you want men to do and then seeing that they do it the best and cheapest ways". __F.W.Taylor

"Management is defined as the creation and maintenance of an internal environment in an enterprise where individuals working together in groups, can perform efficiently and effectively towards the attainment of group goals". __Koontz and O'Donell

"Management is the process of managing people, which involves getting things done through and with others. *- Zene K.Quible -*

"To manage is to forecast and to plan, to organize, to command, to coordinate and to control"
– Henry Fayol -

"Management is simply the process of decision-making and control over the actions of human beings for the express purpose of attaining predetermined goals is called Management" *- Stanley Vance*

MANAGEMENT AS SCIENCE:

1. Science explains phenomenon based upon experimentation, it includes truths, and set of principles known as theory.
2. Science is a systematized body of knowledge developed systematically, based on observation, measurement, and experimentation and drawing inferences based on data.
3. It is useful for to maintain relationship and to follow scientific principles.

The management satisfies the characteristics of science like:

(a) Inferences are drawn based on data analysis.

(b) Management knowledge is developed through observation, measurement and experimentation.

(c) Management knowledge is developed through a number of systems like input-output system, organizational system, and functional system.

MANAGEMENT AS ART:

- Art understands how a particular activity can be done and it can be acquired by conscious effort and practice.
- According to Terry" Art is bringing about of a desired result through application of skill.
- They have to continuously analyze the environment and formulate the plans and strategies.
- The principles of management and theories of management cannot be implemented as learnt, in the real world.
- They are to be applied after making necessary modifications based on the real life situations.
- Art is related with getting results through the application of skills. It is concerned with the understanding of how particular work can be performed, i.e., known-how.

It is more important in management because basically manager's deal with human beings whose behavior is not structured, it is dynamic and unpredictable.

Role of Management:

- The role of management in our society is critical in human progress. It serves to identify a great need of our time; to improve standards of living for all people through effective utilization of human and material resources.
- The role of management has always been taken for granted and under emphasized.
- Technological advancements, levels of production, capital investment and other tangible elements have been emphasized as contributory factors towards economic growth, rather than managerial skills.

Problem Solving Process:

- One of the most important functions of a manager is to make decisions and solve problems.
- Some major problems that the management must continually face include unpredictable economic trends, changing governmental regulations, resource shortages and a severe competition for these resources employee demands technical problems, and technological changes etc.

Ex: A change in production quality can be easily looked into and the process changed, if necessary. An increase in employee grievances or employee absenteeism or turnover may require carefully studied unique solutions.

NATURE OF MANAGEMENT: - The study and application of management techniques in managing the affairs of the organization have changed its nature over a period of time. The following points will describe the nature of management

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4) **Management: Science or Art**: There is a controversy whether management is science or art.

An **art** is personal skill of business affairs. Art is characterized by practical knowledge, personal creativity and skill. The more one practices an art, the more professional one becomes. Management can be considered as an art because it satisfies all these criterion of an art.

A **science** is a systematized body of knowledge of facts. It can establish cause-and-effect relationships among various factors. It involves basic principles, which are capable of universal application. Management can be considered as science because it satisfies all these criterion of a science.

5) **Management as profession**: Management has been regarded as a profession by many while many have suggested that it has not achieved the status of a profession.

Profession refers to a vocation or a branch of advanced learning such as engineering or medicine.

6) **Universality of management**: Management is a universal phenomenon. However, management principles are not universally applicable but are to be modified according to the needs of the situation.

IMPORTANCE OF MANAGEMENT

Management has been important to the daily lives of people and to the organizations. The importance of management may be traces with the following.

1) **Effective utilization of Resources**: Management tries to make effective utilization of various resources. The resources are scarce in nature and to meet the demand of the society, their contribution should be more for the general interests of the society.

Management not only decides in which particular alternative a particular resource should be used, but also takes actions to utilize it in that particular alternative in the best way.

2) **Development of Resources**: Management develops various resources. This is true with human as well as non-human factors. Most of the researchers for resource development are carried on in an organized way and management is involved in these organized activities.

3) **It ensures continuity in the organization**: Continuity is very important in the organizations. Where there are no proper guidelines for decision making continuity cannot be guaranteed. It is quite natural that new people join while some others retire or leave the organization. It is only management that keeps the organization continuing.

4) **Integrating various interest groups**: In the organized efforts, there are various interest groups and they put pressure over other groups for maximum share in the combined output. For example, in case of a business organization, there are various pressure groups such as shareholders, employees, govt. etc. these interest groups have pressure on an organization. Management has to balance these pressures from various interest groups.

5) **Stability in the society**: Management provides stability in the society by changing and modifying the resources in accordance with the changing environment of the society. In the modern age, more emphasis is on new inventions for the betterment of human beings. These inventions make old systems and factors mostly obsolete and inefficient. Management provides integration between traditions and new inventions, and safeguards society from the unfavorable impact of these inventions so that continuity in social process is maintained.

FUNCTIONS OF MANAGEMENT:-

To achieve the organizational objectives managers at all levels of organization should perform different functions. A function is a group of similar activities.

The list of management functions varies from author to author with the number of functions varying from three to eight.

Writers	Management Functions
Henry Fayol	Planning, Organizing, Commanding, Coordinating, Controlling
Luther Gullick	POSDCORD- Planning, Organizing, Staffing, Directing, Coordinating, Reporting, Directing
R. Davis	Planning , Organising, Controlling
E.F.L. Breech	Planning, Organising, Motivating, Coordinating, Controlling
Koontz	Planning, Organising, Staffing, Leading, Controlling

Different authors presented different variations. By combining some of functions, these are broadly grouped into Planning, Organising, Staffing, Directing, and Controlling.

Definition: POSDCORB

POSDCORB is an acronym which means Planning. Organizing, Staffing, Directing, Coordinating, Reporting and Budgeting which was first coined in a paper on administrative management that was written for the Brownlow Committee by Luther Gulick and Lyndall Urwick. POSDCORB can be used as a systematic framework for efficiently executing business processes in a company or by an individual.

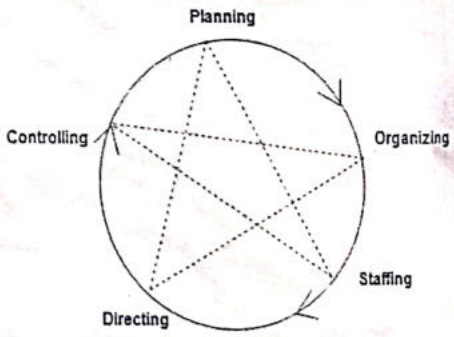
This essentially refers to the various steps or stages involved in a typical administrative process. POSDCORB can be explained in detail below:

1. Planning: This essentially refers to establishing a broad sketch of the work to be completed and the procedures incorporated to implement them.

2. Organizing: Organizing involves formally classifying, defining and synchronizing the various sub-processes or subdivisions of the work to be done.

3. Staffing: This involves recruiting and selecting the right candidates for the job and facilitating their orientation and training while maintaining a favorable work environment.

4. Directing: This entails decision making and delegating structured instructions and orders to execute them.



5. Coordinating: This basically refers to orchestrating and interlinking the various components of the work.

6. Reporting: Reporting involves regularly updating the superior about the progress or the work related activities. The information dissemination can be through records or inspection.

7. Budgeting: Budgeting involves all the activities that under Auditing, Accounting, Fiscal Planning and Control.

Principles of Scientific Management:

Taylor through his principles of scientific management initiated a system in which there would be an effective and fruitful coordination and cooperation between the management and the workers.

i) Development of Science for each element of work:

Analyze the work scientifically, rather than using thumb rule. It means that an attempt is made to find out what is to be done by a particular worker, how he is to do it, what equipment will be necessary to do it. This information is provided to the worker, so as to reduce wastage of tie, material etc. and improve the quality work

ii) Scientific selection, placement and training of workers:

This principle states that select the workers best suited to perform the specific task, and then train tem within the industry in order to attain the objectives of the enterprise workers should also be trained from time to time to keep them informed of latest development in the techniques of production.

iii) Division of Labour:

Division of work in smaller tasks and separation of thinking element of job from doing element of the job, this is the principle of specialization. It is essential for efficiency in all sphere of activities as well as in supervision work

iv) Standardization of methods, procedures, tools and equipment:

Standardization helps in reducing time, labour and cost of production. The success of scientific management largely depends upon standardization of system, depends upon standardization of system, tools, equipments and techniques of production

v) Use of time and motion study:

Taylor's introduced time and motion study to determine standard work. Taylor"s undertook studies on fatigue, incurred by the workers and the time necessary to complete task.

vi) Differential wage system:

Taylor's differential piece rate scheme provides an incentive for a worker to achieve high level of optimum output. It distinguishes the more productive workers from less productive workers and motivates them to produce more.

vii) Co-operation between labour and management:

Mutual respect and cooperation between the workers and management helps in providing proper and effective leadership. The labour starts thinking that it is their work and they must put their heart in the work assigned to him.

viii) Principle of Management by Exception:

Taylor suggested that only major or significant deviations between the actual performance and standard performance should be brought to the notice of top management. Top management should pay more attention to those areas of work where standards and procedures could not be established and where there is a significant variation between standard performance and actual perform.

FAYOLS PRINCIPLES OF MANAGEMENT

Henri Fayol is called as father of Modern Management

He established the pattern of management and the pyramidal form of organization. He pointed out that technical ability is more dominating on the lower level of management managerial ability is more important on the higher level of management.

Henri Fayol analyzed the process of management and divided the activities of an industrial undertaking into six groups

(i) Technical activities (relating to production);

(ii) Commercial activities (buying, selling and exchange);

(iii) Financial activities (search for capital and its optimum use)

(iv) Security activities (protection of property and persons);

(v) Accounting activities (Preparation of various statements, accounts, returns etc.) and

(vi) Managerial activities (planning, organization, command, co-ordination and control)

GENERAL PRINCIPLES OF MANAGEMENT:

H.Fayol has given 14 principles of management. He has made distinction between management principles and management elements. While management principles is a fundamental truth and establishes cause effect relationship, elements of management denotes the function performed by a manager.

While giving the management principles, Fayol has emphasized two things.

1. The list of management principles is not exhaustive but suggestive and has discussed only those principles which he followed on most occasions.
2. principles of management are not rigid but flexible

Principles:-

1. **Division of work**: It is helpful to take the advantage of specialization. Here, the work is divided among the members of the group based on the employees skills and talents. It can be applied at all levels of the organization.
2. **Authority and Responsibility**: Fayol finds authority as a continuation of official and personal factors. Official authority is derived from the manager's position and personal authority is derived from personal qualities such as intelligence, experience, moral worth, past services, etc., Responsibility arises out of assignment of activity. In order to discharge the responsibility properly, there should be parity between authority and responsibility.
3. **Discipline**: All the personal serving in an organization should be disciplined. Discipline is obedience, application, behavior and outward mark of respect shown by employees.
4. **Unity of Command**: Unity of command means that a person should get orders from only one superior. Fayol has considered unity of command as an important aspect in managing an organization. He says that "should it be violated, authority is undermined, discipline is in jeopardy, order disturbed, and stability threatened."
5. **Unity of Direction:** According to this principle, each group of activities with the same objective must have one head and one plan. It is concerned with functioning of the organization I respect of grouping of activities or planning. Unity of direction provides better coordination among various activities to be undertaken by an organization.
6. **Subordination of individual interest to general interest**: Individual interest must be subordinate to general interest when there is conflict between the two. However factors like

ambition, laziness, weakness, etc., tend to reduce the importance of general interest. Therefore, superiors should set an example in fairness and goodness.

7. **Remuneration to Personnel**: Remuneration to employees should be fair and provide maximum possible satisfaction to employees and employers. Fayol did not favor profit sharing plan for workers but advocated it for managers. He was also in favor of non-financial benefits.
8. **Centralization**: Everything which goes to increase the importance of subordinate's role is decentralization; everything which goes to reduce it is centralization. The degree of centralization or decentralization is determined by the needs of the company.
9. **Scalar Chain**: There should be a scalar chain of authority and of communication ranging from the highest to the lowest. It suggests that each communication going up or coming down must flow through each position in the line of authority. It can be short-circuited only in special circumstances. For this purpose, Fayol has suggested 'gang plank'
10. **Order:** This is a principle relating to the arrangement of things and people. In material order, there should be a place for everything and everything should be in its place. Similarly, in social order, there should be the right man in the right place.
11. **Equity:** Equity is the combination of justice and kindness. Equity in treatment and behavior is liked by everyone and it brings loyalty in the organization. The application of equity requires good sense, experience and good nature.
12. **Stability of tenure:** No employee should be removed within short time. There should be reasonable security of jobs. Stability of tenure is essential to get an employee accustomed to new work and succeeding in doing it well.
13. **Initiative:** Within the limits of authority and discipline, managers should encourage their employees for taking initiative. Initiative is concerned with thinking out and execution of a plan. Initiative increases zeal and energy on the part of human beings.
14. **Esprit de corps:** It is the principle of 'union is strength' and extension of unity of command for establishing team work. The manager should encourage esprit de corps among his employees.

SYSTEMS APPROACH:

Def: A system may be defined "As an orderly grouping of separate but interdependent components for the purpose of attaining some predetermined objective". This definition leads to three important aspects.

- The management of components must be orderly and hierarchical, no matter how complex the "whole: may be.
- Since the components of the system are interdependent, there must be communication among them.
- Since a system is oriented towards an objective, any interaction among the components must be designed to achieve that objective.

The systems theory looks at the organization as a whole examining all relevant organizational variables simultaneously. The approach is to identify the parts of the organization and to discover how these parts operate interdependently.

The system approach school is of recent origin having developed in late 1960's.

Main features:

1. A system has a number of sub-systems, parts and subparts.
2. All the subsystems, parts and subparts are manually related to each other. The relationship is in the context of the whole and is very complex. A change in one part will effect changes in others.
3. The systems approach emphasizes the study of the various parts in their interrelationships rather than in isolation from each other.
4. The system approach to management brings out the complexity of a real life approaches.

Characteristics:

- Every system is comprised of many subsystems which are interacting with each other.
- It is a complex and interrelated in a such a manner that a change in one variable will effect a change in others.
- A system has a tendency to remain in equilibrium by maintaing a balance among the various forces operating within and upon it.
- A system cannot exist in isolation. It must gets inputs from some other system and its outputs become inputs to other systems.
- Each entity processes this information or energy in its own way and sends its output to the rest of the system and to the external world.

Uses:

- The systems approach has been used in studying the function of complex organizations and as the base for new kinds of organization like the project management organization.
- The systems approach has an edge over the other approaches in so far as its closeness to reality is concerned.
- Limitation; the problem with the systems approach is its utter complexity particularly when it comes to a study of large and compels organizations.

Difference between Production Engineering and Industrial Engineering

Aspect	Production Engineering	Industrial Engineering
Definition	Concerned with the design, operation, and control of manufacturing processes to produce goods.	Concerned with optimizing systems involving people, materials, machines, money, and information.
Focus Area	Manufacturing processes, machines, tools, and production methods.	Efficiency, productivity, cost reduction, and system optimization.
Main Objective	To manufacture quality products at minimum cost using effective production techniques.	To improve overall system performance by eliminating waste and improving workflow.
Core Subjects	Manufacturing processes, CAD/CAM, CNC machines, tool design, metallurgy.	Work study, operations research, production planning and control, quality management.
Role of Human Factor	Limited focus on human and ergonomic aspects.	Strong focus on human factors, ergonomics, and work measurement.
Application Level	Shop-floor and machine-level operations.	Organization-wide systems and managerial decision-making.
Decision Making	Mainly technical and process-based decisions.	Analytical and managerial decisions using mathematical and statistical tools.
Career Roles	Production engineer, manufacturing engineer, process engineer.	Industrial engineer, operations manager, quality engineer, supply chain analyst.

- **Production Engineering** deals with *"how to manufacture the product."*
- **Industrial Engineering** deals with *"how to manufacture efficiently."*

. Definition of Industrial Engineering (I.E.)

Industrial Engineering is a branch of engineering that deals with the **design, improvement, and installation of integrated systems** involving **people, materials, machines, information, energy, and money** to produce goods or services efficiently.

☞ According to the **American Institute of Industrial and Systems Engineers (IISE):**
"Industrial engineering is concerned with the design, improvement, and installation of integrated systems of people, materials, information, equipment, and energy."

Main objective:
✓ Increase productivity
✓ Reduce cost and waste
✓ Improve quality and safety
✓ Optimize use of resources

2. Development of Industrial Engineering

The development of Industrial Engineering took place in **stages**, mainly driven by industrial growth.

(a) Early Stage (Pre-1900)

- Craft system and manual production
- Little standardization
- Low productivity

(b) Scientific Management Era (1900–1930)

- **Frederick W. Taylor** – *Father of Scientific Management*
- Introduction of:
    - Time study
    - Motion study
    - Standardization of work
- Focus on improving worker efficiency

(c) Human Relations Era (1930–1950)

- Emphasis on:
    - Worker motivation
    - Job satisfaction
    - Human factors
- **Elton Mayo's Hawthorne Experiments**

(d) Operations Research & Systems Approach (1950–1980)

- Use of mathematics and statistics

- Development of:
    - Linear programming
    - Inventory models
    - Queuing theory
- Decision-making based on scientific methods

(e) Modern Industrial Engineering (1980–Present)

- Computer-based techniques
- Concepts such as:
    - Automation
    - CAD/CAM
    - Lean manufacturing
    - Six Sigma
    - Industry 4.0
- Focus on global competitiveness and sustainability

3. Applications of Industrial Engineering

Industrial Engineering is applied in **both manufacturing and service sectors.**

(a) Manufacturing Industry

- Plant layout and material handling
- Production planning and control
- Work study and method study
- Quality control and assurance
- Inventory management
- Cost reduction

(b) Service Industry

- Hospitals (patient flow, scheduling)
- Banks and financial institutions
- Transportation and logistics
- Retail and supply chain management
- IT and software services

(c) Other Areas

- Project management
- Ergonomics and safety engineering
- Operations management
- Environmental and waste management
- Maintenance planning

4. Role of an Industrial Engineer

An **Industrial Engineer** plays a key role in improving system performance and efficiency.

Major Roles:

1. **Productivity Improvement**
    - Analyze and improve work methods
    - Reduce idle time and bottlenecks
2. **Cost Reduction**
    - Minimize waste
    - Optimize resource utilization
3. **System Design**
    - Design efficient layouts
    - Improve workflows and processes
4. **Quality Improvement**
    - Implement quality control techniques
    - Reduce defects and rework
5. **Human Factors & Safety**
    - Improve workplace ergonomics
    - Ensure worker safety and comfort
6. **Decision Making**
    - Use data analysis and optimization tools
    - Support management in planning and control
7. **Coordination Role**
    - Act as a link between management and workers
    - Integrate technical and human elements

Production Engineering and Industrial Engineering

1. Focus and Scope

- **Production Engineering:**
  - **Focus:** Primarily focuses on the design, operation, and optimization of production systems. This includes the processes and technologies used in manufacturing to produce goods efficiently.
  - **Scope:** Covers everything related to manufacturing processes, from material selection, machinery, tools, and automation systems to the implementation of production schedules and quality control.
- **Industrial Engineering:**
  - **Focus:** Industrial engineering deals with optimizing complex systems, processes, and organizations. It emphasizes improving productivity, efficiency, and quality while considering both human and machine factors in the production process.
  - **Scope:** More expansive, covering fields like supply chain management, operations research, ergonomics, inventory control, logistics, quality assurance, and human resource management.

2. Key Objectives

- **Production Engineering:**
  - Improve manufacturing processes and methods.
  - Ensure efficient resource utilization, including machinery, materials, and labor.
  - Focus on achieving high productivity and product quality with minimized costs.
- **Industrial Engineering:**
  - Improve overall efficiency and productivity by analyzing and optimizing various processes in manufacturing, healthcare, logistics, and service sectors.
  - Focuses not only on production but on improving operational efficiency at an organizational level, often through the use of mathematical models, simulations, and process design techniques.

3. Core Disciplines

- **Production Engineering:**
  - Involves knowledge in **materials science, mechanical engineering, manufacturing processes** (casting, welding, molding), **machining**, and **automation.**
  - Emphasizes hands-on engineering skills and understanding of the manufacturing technologies required to produce products.
- **Industrial Engineering:**
  - Includes **operations research, systems engineering, logistics, supply chain management, optimization techniques,** and **human factors engineering.**

- Focuses on **mathematical modeling, data analysis**, and the design of systems that are effective and efficient in terms of human, machine, and material resources.

4. Approach to Problem-Solving

- **Production Engineering:**
  - Uses a more **technical and practical** approach to solving problems, focusing on the **hardware, machinery, and physical production processes.**
  - Typically applies solutions that ensure smooth production flow, minimize downtime, and improve the quality and output of machines and workers.
- **Industrial Engineering:**
  - Tends to take a **systemic and holistic approach** to problem-solving, considering **human, organizational, and technological factors** in decision-making.
  - Often uses **mathematical tools** (like linear programming, queuing theory) and **statistical methods** (like Six Sigma) to enhance efficiency and reduce waste across various operations.

5. Nature of Work

- **Production Engineering:**
  - Engineers in this field usually work directly in **manufacturing plants** or in **workshops**, focusing on **product design, process improvement, equipment maintenance**, and **optimization of production lines.**
  - Responsibilities might include selecting materials, designing production tools, and maintaining production machinery.
- **Industrial Engineering:**
  - Work can be more diverse, ranging from **factories** to **offices** and even **healthcare systems**. Industrial engineers may not always work with physical machines but focus on improving business systems, logistics, and workflow through **data analysis** and **optimization.**
  - They may work on improving overall system performance, reducing costs, and ensuring the efficient movement of goods and services.

6. Skill Set

- **Production Engineering:**
  - Requires expertise in **manufacturing processes, CAD/CAM software, machine tool operation, quality control**, and **supply chain logistics.**
  - Strong knowledge in **mechanical design, materials science**, and **automation technologies** is key.
- **Industrial Engineering:**
  - Requires proficiency in **operations research, system analysis, statistics, forecasting**, and **project management.**
  - Analytical skills, data modeling, and a deep understanding of **supply chain management** and **process design** are essential.

7. Educational Path

- **Production Engineering:**
  - Students pursuing this discipline typically study **mechanical engineering**, with specialized courses in **manufacturing processes, automation, materials science**, and **industrial tools**.
  - A production engineering program often includes **practical training** in industrial environments, alongside theory-based learning in machinery and process management.
- **Industrial Engineering:**
  - Industrial engineering students study a broad range of subjects, including **engineering economics, systems theory, human factors engineering, operations research**, and **production planning**.
  - The focus is more on systems optimization, with less emphasis on technical manufacturing processes compared to production engineering.

8. Career Opportunities

- **Production Engineering:**
  - Careers are mostly in **manufacturing industries**, where engineers are needed to oversee the production process, quality control, machinery maintenance, and efficiency improvement.
  - Roles include **production manager, manufacturing engineer, process engineer**, and **maintenance engineer**.
- **Industrial Engineering:**
  - Careers are more diverse and can be found in a range of industries, including **consulting, logistics, supply chain management, operations management**, and even **healthcare systems**.
  - Roles include **industrial engineer, operations manager, supply chain analyst**, and **logistics coordinator**.

9. Use of Technology

- **Production Engineering:**
  - Involves a lot of hands-on work with **manufacturing technologies**, including **robotics, CNC machines, automated production systems**, and **3D printing**.
  - Often involves **software tools** for designing and optimizing production lines and equipment (e.g., CAD software).
- **Industrial Engineering:**
  - Makes extensive use of **software for simulation** (like Simul8, Arena), **supply chain management systems** (like SAP), and **decision support systems** to optimize operations and resource allocation.
  - Also uses advanced **data analysis tools**, including **statistical software** (e.g., Minitab, R) for improving systems.

10. Organizational Impact

- **Production Engineering:**

- Aims at improving the **efficiency of manufacturing processes** directly on the shop floor. This can lead to increased output, lower production costs, and better quality products.

- **Industrial Engineering**:
  - Focuses on optimizing the **entire organization**, from the ground up, often considering how departments interact, human factors, supply chain efficiency, and business workflows.
  - The goal is often to reduce operational costs across the entire system, streamline processes, and improve overall productivity.

Conclusion:

In summary, **Production Engineering** is more focused on the technical aspects of manufacturing products, while **Industrial Engineering** looks at optimizing systems, processes, and workflows on a larger scale, incorporating human and technological factors. Both fields are essential for improving efficiency, but they approach it from different angles: one from the **machine and process** perspective (Production Engineering) and the other from a **system and organizational optimization** perspective (Industrial Engineering).

Productivity Measurement

Productivity measurement is a key concept in management and engineering, used to evaluate the efficiency of production processes and overall operations. It is a way to determine how effectively resources (such as labor, capital, and materials) are being used to produce goods and services.

Definition of Productivity

- **Productivity** refers to the ratio of output to input in a production process. It is a measure of how effectively resources (like labor, capital, and raw materials) are used to produce goods and services.

  Formula:

- Productivity= Output /Input

- Where output is the quantity of goods and services produced, and input is the quantity of resources used (such as labor hours, materials, or capital).

2) Types of Productivity

There are several ways to measure productivity based on the type of resources being considered:

- **Labor Productivity**: Measures the output produced per unit of labor input (usually in terms of labor hours or number of workers).

Productivity Measurement: Detailed Overview

Productivity measurement is a key concept in management and engineering, used to evaluate the efficiency of production processes and overall operations. It is a way to determine how effectively resources (such as labor, capital, and materials) are being used to produce goods and services. In a detailed 10-mark format, the following points will help break down the key aspects of productivity measurement:

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1. Definition of Productivity

- **Productivity** refers to the ratio of output to input in a production process. It is a measure of how effectively resources (like labor, capital, and raw materials) are used to produce goods and services.
- **Formula:**

$$\text{productivity} = \frac{\text{output}}{\text{input}}$$

Where output is the quantity of goods and services produced, and input is the quantity of resources used (such as labor hours, materials, or capital).

---

2. Types of Productivity

There are several ways to measure productivity based on the type of resources being considered:

- **Labor Productivity**: Measures the output produced per unit of labor input (usually in terms of labor hours or number of workers).

$$\text{labour } p = \frac{\text{output}}{\text{labour hours.}}$$

lab mlc

- **Capital Productivity**: Measures the output generated per unit of capital input (e.g., machinery, equipment, or financial investments).

$$\text{machine } p = \frac{\text{output}}{\text{m/c hours.}}$$

- **Material Productivity**: Focuses on the efficiency of material usage in the production process.

$$\text{material } p = \frac{\text{output}}{\text{m/l used}}$$

- **Total Factor Productivity (TFP)**: Measures the overall efficiency of all inputs, taking into account labor, capital, materials, and energy.

$$TFP = \frac{\text{output}}{\text{labour + capital}}$$

→ Total productivity $= \frac{\text{total dp}}{\text{labour + capital + materials + energy + overheads.}}$

3. Productivity Metrics

To evaluate productivity accurately, several **metrics** and tools are used. These metrics help compare the efficiency across different production processes, industries, or time periods:

- **Output per Labor Hour**: A common metric for measuring labor productivity. It shows how many units of product are produced per hour worked.
- **Output per Worker**: Measures how many units of product are produced by each worker within a given period (e.g., per day, week, month).
- **Return on Investment (ROI)**: A financial metric that evaluates the profitability of an investment relative to its cost. It indirectly measures the productivity of capital.

4. Methods for Measuring Productivity

There are several methods to measure productivity depending on the complexity of the system and the availability of data. Some common methods include:

- **Single-Factor Productivity (SFP)**:
  - Measures the output-to-input ratio for one factor (e.g., labor, capital, or materials).
  - Formula:

    - Example: Labor productivity, where the output is divided by the number of labor hours worked.

- **Multi-Factor Productivity (MFP):**
  - Takes multiple inputs into account, such as labor, materials, and capital, to give a more comprehensive measure of productivity.
  - Example: If a company wants to assess the combined efficiency of labor, materials, and capital in producing a certain product.
- **Total Factor Productivity (TFP):**
  - Measures the efficiency with which all inputs are used to produce output. It is particularly useful when the organization or economy is interested in improving the performance of the entire system.
  - Formula:
  - TFP captures improvements in technology, process innovations, and other efficiency factors that are not directly related to increases in input quantities.

5. Importance of Measuring Productivity

- **Efficiency Evaluation:** Helps to determine how efficiently the available resources are being used to produce goods or services. High productivity typically reflects efficient use of resources.
- **Cost Reduction:** By measuring and optimizing productivity, organizations can reduce costs, improve competitiveness, and increase profitability.
- **Performance Benchmarking:** Productivity measurement allows companies to compare their performance against industry standards or competitors. This helps in setting realistic goals and improving operational practices.
- **Identifying Improvement Areas:** Productivity measurements identify where improvements can be made. This might be in processes, training, equipment, or supply chain management.
- **Economic Growth Indicator:** On a national or global scale, productivity is a crucial indicator of economic health. An increase in productivity often leads to higher output and living standards.

6. Factors Affecting Productivity

Several internal and external factors influence productivity measurements:

- **Technological Advancements**: The introduction of new technologies often leads to increased productivity by automating processes or improving production methods.
- **Training and Skills of Workers**: Well-trained and skilled workers tend to be more productive, as they can work more efficiently and make fewer errors.
- **Management and Organization**: Effective management practices, good leadership, and clear organizational structures help streamline operations, reducing waste and improving productivity.
- **Availability of Resources**: Availability and quality of resources, such as materials, machinery, and capital, have a significant impact on productivity. A shortage of resources can hinder production.
- **Economic Conditions**: Inflation, market demand, and labor costs are factors outside the organization that can influence productivity.

7. Productivity Improvement Strategies

- **Process Optimization**: Streamlining production processes to reduce waste, reduce time, and improve quality.
- **Automation and Technology Integration**: Using advanced technologies like robotics, AI, and machine learning to increase the speed and accuracy of production.
- **Employee Engagement**: Motivating employees, providing training, and improving working conditions to enhance labor productivity.
- **Lean Manufacturing**: Adopting lean techniques to minimize waste, improve workflow, and reduce inefficiencies in the production process.
- **Standardization**: Implementing standardized processes to ensure consistency and efficiency in production.

8. Limitations of Productivity Measurement

- **Quality vs. Quantity**: Focusing only on output can ignore the quality of the product, which might impact customer satisfaction.
- **External Factors**: External factors such as supply chain disruptions, economic downturns, or regulatory changes can affect productivity but are outside the control of the organization.
- **Diminishing Returns**: Increasing input does not always result in proportional increases in output. Beyond a certain point, productivity gains may reduce as more resources are used.
- **Non-Quantifiable Inputs**: Some inputs like employee creativity, management skill, and innovation are difficult to quantify but can significantly impact overall productivity.

9. Example of Productivity Measurement

Consider a manufacturing company that produces mobile phones. If the company wants to assess labor productivity, the following formula could be used:

- **Output**: 1,000 mobile phones produced.
- **Labor Input**: 500 hours worked by employees.

unit-3

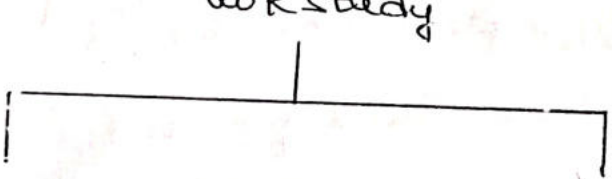
UNIT-V

Work study :-

Work study aims at determining the best method of doing a job and to determine the standard time for completion of a job.

A qualified worker should take to preform the operation working at normal place.

Work study has 2 Techniques



method study
(or)
motion study
(How a job should be done?)

work measurement
(or)
Time study
(How much time a job should take for completic

Objectives of work study :-

(1) Effective utilisation of men, machines, materials.
(2) Better product quality.
(3) Less fatigue (failures) to operators and workers.
(4) To determine the time required for a job
(5) To decide equipment requirements.
(6) To decide realistic labour budgeting.
(7) To aid in exact delivery dates.

Advantages of work study :-

(1) Higher productive efficiency - by improving the method

(2) Reduced manufacturing costs - through minizing waste involved at various stages of work.

(3) Fast & accurate delivery dates

(4) work standarization - by providing suitable tools jigs, fixtures, material handling equipment etc.

(5) Effective utilisation of resources - It enables to use the men, material, machines to more effectively.

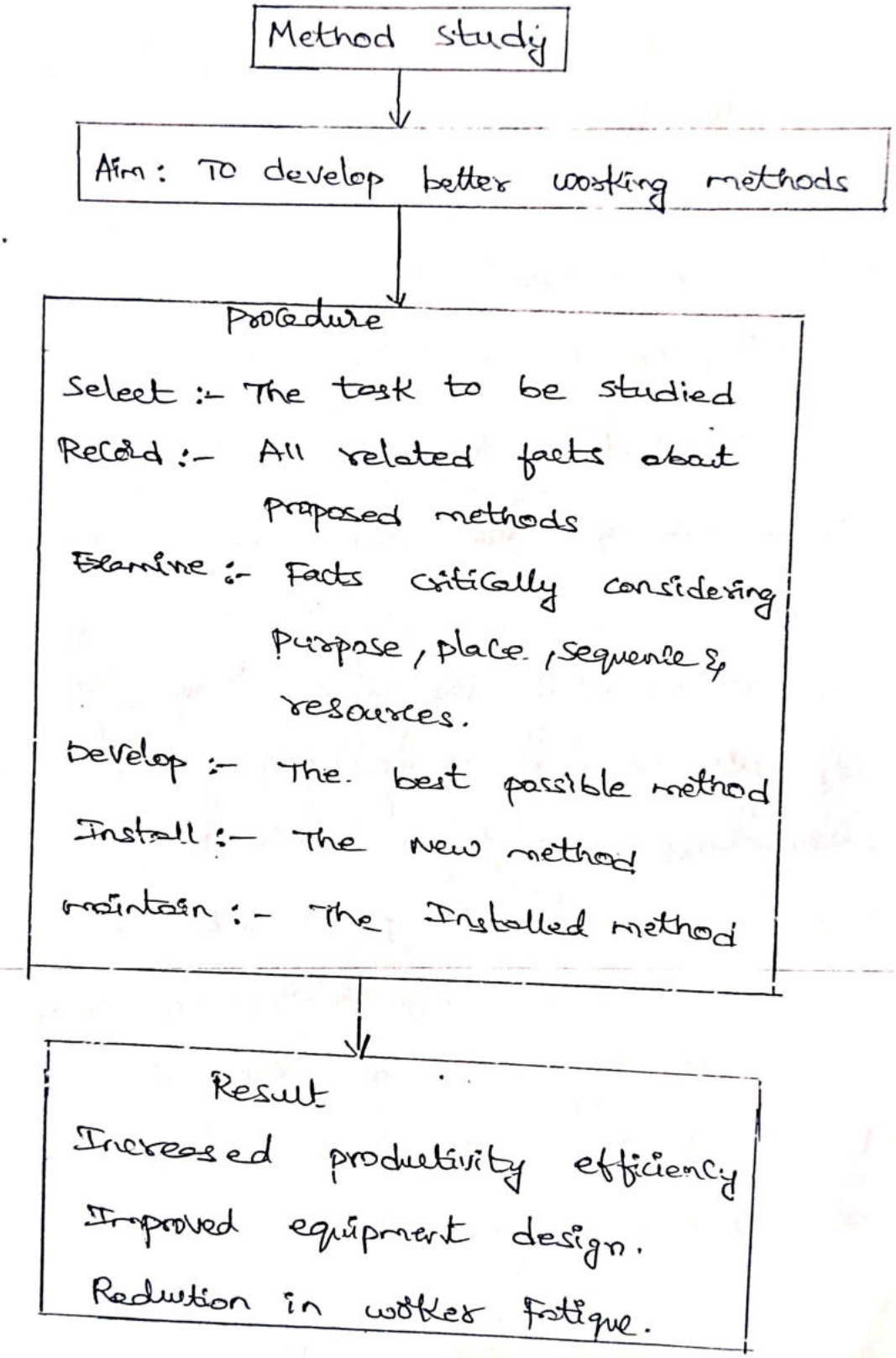
(6) Efficient material handling - It ensures the smooth and fast material handling without breaking.

Basic procedure (or) steps involved in Method Study :-

Method study :-

Method study is defined as the "Systematic recording and critical examination of existing and proposed ways of doing work as a means of developing and applying easier and more efficient method.

Basic procedure of method study :-



Objectives of method study :-

(1) To find out the best way of doing a job.

(2) To eliminate waste of time and labour.

(3) To have more effective utilisation of materials, machines & workers.

(4) To improve the design of work place layout.

Steps involved in the method study :-

The process of method study involves the following procedure :

(1) Selection - Select the (work) task to which the method study principles are to be applied and drawbacks regarding that work to be specified.

(2) Record - The existing process (&) method of doing has to be recorded. Every detail, even though it is small, to be identified and recorded.

Relevant information is recorded using process chart symbols indicated as below.

different symbols used in process charts are presented in given below :-

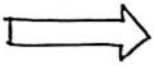
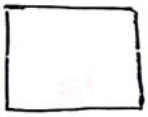
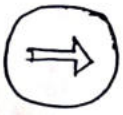
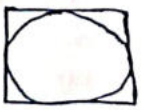
(a) Process chart :-

A chart representing a process is called as a process chart. A process chart records the sequence of operations connected with process graphically & diagrammatically.

The recording is done with the use of process chart symbols. These symbols helps us to understand and examin the process in a better way.

The symbols are

Event	Symbol	Description
Operation		Operation means an action. It is one of the steps in the procedure. An operation is making, altering or changing a job. Ex:- Cutting wood in wood using a saw.; driving rivet in a sheet metal.
Storage		It is the stage of a finished good or raw material waiting for an action. Ex;- A finished product in a stock room.

Delay (D) Temporary Storage		Delay means the process has stopped due to some reason and the product is waiting for the next event. Ex:- power failure, waiting for lift etc.
Transport		It represent the movement of an item form one location to another. The item may be an equipment, material or an operator. Material sent from stores to site
Inspection		It represents checking for quality & quantity of the items. checking hardness of a material, measuring the diameter of a rod.
operation cum Transport		Ex:- painting a product as it is being transported by a chain conveyor.
Inspection cum operation		Ex:- An automatic process where a grease tin is weighted i.e inspected as it is filled.

(3) Examine :-

The recorded events critically and in sequence. Critical examination involves answer to a number of questions.

An activity can be eliminated, simplified or combined with another. The basic questions are

Purpose : what is done?

Person : who does it?

Means : How is it done?

Sequence : when is it done?

(4) Develop :-

The best method as resulted from critical examination and record it. The developed method should be.

(i) practical and feasible.

(ii) safe and executive.

(iii) Economical

(iv) Acceptable to design, production control, quality control and sales departments.

(5) Install :- The best (&) developed method (of) the improved method. Installation involves 3 phases namely.

planning, arranging & implementing.

During first two stages the programme of installation and a time table, are planned and the necessary arrangements of resource, equipments, tools and instructions to workers, over time etc are made. The implementation (or actual installation involves the introduction of developed method as standard practice.

(6) Maintain:-

the new method .. i.e ensure the proper functioning of the installed method by periodic checks & verification.

Once, the new method starts yielding the desired results, it is necessary to maintain the new method without any change for sometime.

Recording Technique:-

Various types of associated charts:-

(1) Process charts:-

There are three types of associated charts. They are:-

(i) outline process chart.

(ii) two handed process chart (operator activity chart)

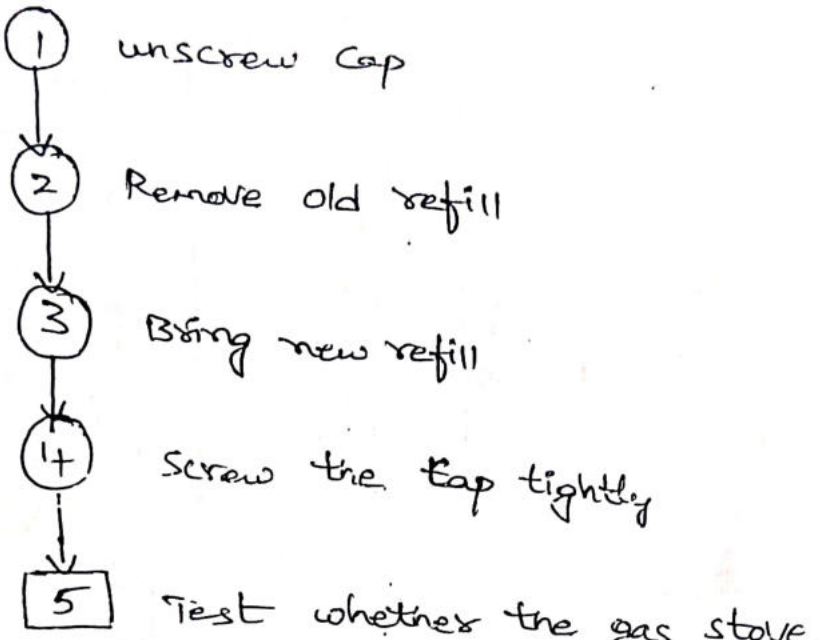
(iii) flow process chart

(2) Diagrams

(3) motion & film analysis.

(1) Outline process chart :-

This chart outlines the main events sequence-wise considering only operations and inspections in the given job.



(2) Two handed process chart :-

This presents the simultaneous activities of both the right & and left hand of an operator during work of short and repetitive nature.

For certain jobs such as typing, watch repair, nail hitting, cooking & repair of consumer durables such as fridges, TV & so on.

using both hands one of hand may be free &

Supporting the other hand.

Let us see both the hands of operator are involved in the simple job of nail hitting.

Left hand	Symbols		Right hand
	Left hand	Right hand	
pick up nail			pick up the hammer
Fix the nail at required point on box.			Idle
Hold			Strike
Idle			Inspect

The purpose of this chart is to depict the existing method of doing the job. This will be the basis for a detailed examination as to where we can recognise some of the elements in a finer way to take lesser time.

Flow process chart :-

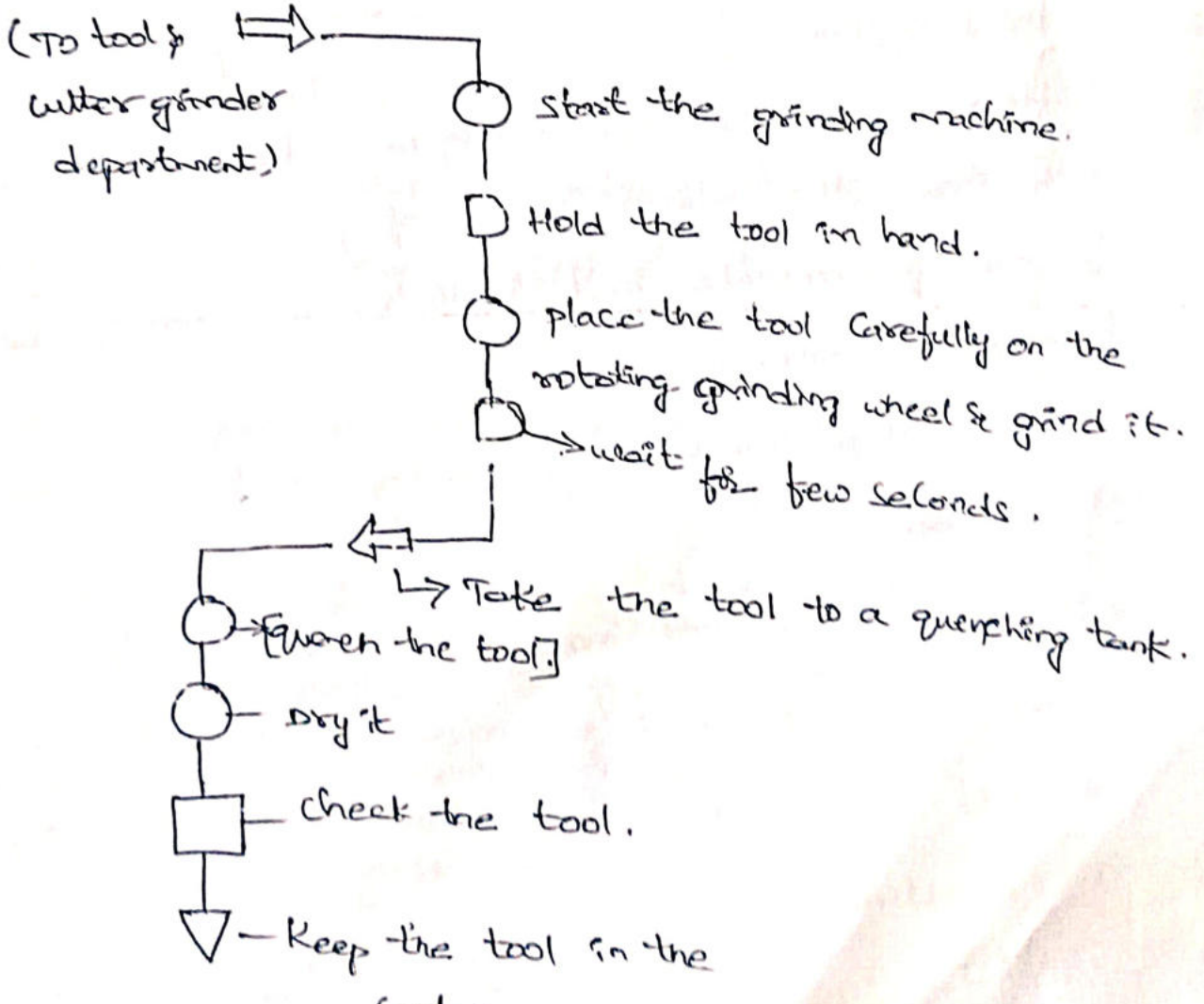
This is a detailed version of the outline process chart and it records all the events.

A flow process chart records all the events in sequence using process chart symbols and marks distance and time taken for completing an activity.

There are three types of flow process charts namely.

(1) Flow process chart (men)
(2) Flow process chart (equipment)
(3) Flow process chart (material)

Flow pro



Flow process charts for men records the activities of an operator.

Flow process charts for equipment record the manner in which the equipment is used.

Flow process chart for materials record what happens to the material with respect to location & condition.

(2) Diagrams :-

(1) Flow Diagram

(2) String diagram.

(1) Flow Diagram :-

A flow diagram which is a diagram drawn to scale which shows the relative position of production machinery, Jigs and fixtures etc and indicates the path followed by men and materials.

The steps involved in drawing a flow diagram, is given below.

a) The plan of the work area is drawn to scale.

b) The relative positions of various facilities such as machines, stores, area of inspection etc are marked.

c) The actual path movements of the workers & material along with the direction of movement is indicated

(2) String Diagram :- (In which string/thread is used in place of lines) String diagram is a model of a scale plan of the shop, measure dist. in which every machine or equipment is marked and a pin is struck by it in the area representing a facility.

A continuous colored thread or string traces the path taken by the materials or workers while performing a particular operation.

Micromotion study :-

Micromotion study, which was originated by Frank B. Gilbreth is one of the most exciting forms of work analysis available for job improvement.

→ It is an analysis technique making use of motion pictures (or) Video (or) Videotape taken at constant and known speed.

→ It leaves a permanent record of both the method being used and the time consumed in doing the work.

→ Although micromotion study made use of motion pictures, very few companies today are using them.

→ As Indicated earlier, videotape equipment has been developed so extensively.

→ It provides a valuable technique for making minute

analyses of those operations that are short in cycle, contain rapid movements and involve high production over a long period of time.

→ It is very useful in analysing operations such as sewing of garments, assembly of small parts and similar activities.

Memomotion study :-

Memomotion study which was originated by M.E. Mundel is special form of micromotion study in which motion pictures & videotape are taken at low speeds.

→ It has been used to study the flow and handling of materials, crew activities, multiperson and machine relationships, stock room activities, department store clerks, and a variety of other jobs.

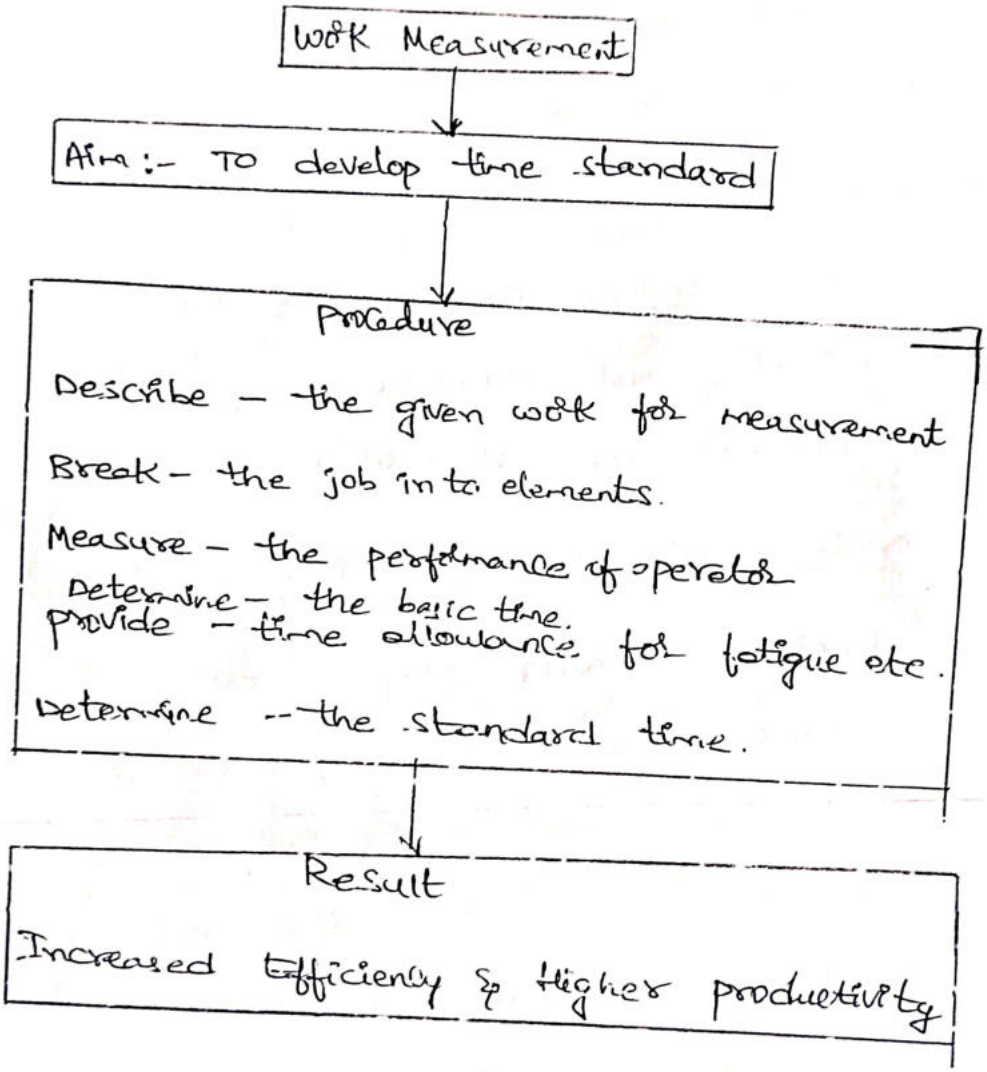
→ It is particularly valuable on long cycle jobs & jobs involving many interrelationships.

Work Measurement :-

It is to determine how much time a job should take for completion of work.

It is defined as determining a standard time taken by a qualified worker to complete a specified job at a defined level of performance.

Procedure for work measurement :-



Time study Equipments :-

Time study equipments can be broadly grouped under two categories :

(a) Time measuring devices.

(b) Time study boards

Time measuring devices :-

There are four types of time measuring devices

(a) stop watch

(b) motion picture Camera

(c) time recording machines.

(d) electronic timer.

(1) stop watch :-

Stop watches can be of two types :

(1) Decimal minute stop watch .

(2) Decimal hour stop watch

(i) Decimal minute stop watch :-

Decimal minute stop watch has a dial which is divided into 100 equal parts. The needle completes one revolution in one minute. The least count in this watch is 0.01 minute. The total time is also recorded in minutes by another small dial in this watch. This small dial has 30 equal spaces and the small needle on this dial makes one complete revolution in thirty minutes.

(ii) Decimal hour stop watch :-

The dial in which this watch is divided in to 100 parts.

The needle completes 10 revolutions in one hour. The least count in this watch is 0.001 hour. The small dial of this watch is divided into 30 equal spaces (representing 0.01 hour), and the small needle makes 3 1/3 revolutions in one hour.

(2) Motion picture Camera :-

Every element of the operation involving various motions of the worker is made into a film through motion picture camera. When this film is run at a slow speed through a projector, the timing of each element is recorded using a stop watch.

(3) Time recording machine :-

A moving tape is run in this machine at a uniform velocity of 10 inches/minutes with the help of electric motor. The machine has two keys : one key, when pressed, indicates starting of an operation, and the other key is used to take a print on the scaled tape at the end of an element.

(4) Electronic timer :-

The timing of starting and ending of an operation of a element is automatically recorded through electronic timers. precision and accuracy are the great features of the electronic timer.

Time study boards :-

These are simple and hard wood boards equipped with stopwatch holders and clamps for holding the observation sheets and time study forms. These boards help to see and record the observations and time at the same instant.

Number of observations :-

While computing the basic time, it is always safe to take average time taken by the worker to complete certain element in a given task.

For ±5 percent accuracy & 95 percent confidence level, the minimum no of observations necessary can be calculated with the relation given below.

$$N = \left[40 \frac{\sqrt{n \Sigma(Fx^2) - (\Sigma Fx)^2}}{\Sigma(Fx)} \right]^2$$

where $n = \Sigma F$ = No of observations taken

N = No of observations required for 95% confidence level & ±5% accuracy.

X = Value of observations.

Total no of observations required = 86

86 - 40 = 46

Still 46 observations are required to get average time.

Work Sampling :- (Active Sampling)

It is a technique in which large no of observd are made over a period of time for either a single machine / process or worker or a group of these. Each observation recorder what is happening at a given point of time.

For instance, when 500 random observations are taken in 10 days in a factory. 350 times the worker were found working & 150 times not working. That means that every day 70% of time worker are working & 30% of time not working.

Work sampling is used where management wants to

→ know the % of idle time for worker in a factory wit hundreds of machines & thousands of workers.

→ establish the standard time for an operation.

→ fix the performance rate.

Number of observations :-

$$S \times p = 2\sqrt{\frac{p(1-p)}{n}} \quad (\text{or}) \quad n = \frac{4p(1-p)}{S^2 \times p^2}$$

where S = desired relative accuracy

p = % occurance of an activity (or) delay being measured, (or) expressed as a % of total No of observations as decim

n = total no of observations.

(1) Calculate the No of observations required for an accuracy of ±5 percent & confidence level of 95 percent, if $p = 0.5$

Given $S = \pm 5 = 0.05 \quad p = 0.5$

$$n = \frac{4p(1-p)}{S^2 \times p^2}$$

$$= \frac{4 \times 0.5(1-0.5)}{(0.05)^2 \times (0.5)^2}$$

$$= \frac{1}{0.000625}$$

$$n = 1600 \text{ observations.}$$

Ex(1)

For a particular task 43 observations were taken by a time study observer. Check whether this no of observation are sufficient at 95% confidence level with ±5% accuracy. Find the minimum no of observations required

Time (x)	3	4	5
Frequency (f)	15	20	8

Sol

x	f	fx	x^2	fx^2
3	15	45	9	135
4	20	80	16	320
5	8	40	25	200
	$n = \Sigma f = 43$	$\Sigma(fx) = 165$		$\Sigma(fx^2) = 655$

$$N = \left[40 \frac{\sqrt{n \Sigma(fx^2) - (\Sigma fx)^2}}{\Sigma(fx)} \right]^2$$

$$= \left[40 \frac{\sqrt{43 \times (655) - (165)^2}}{165} \right]^2$$

$$= 55.24 = 55 \text{ observations.}$$

Present no of observations is 43, we need 12 more observations to calculate average time (55 − 43 = 12).

(2) For a particular task 40 observations were taken by a time study observer. check whether the no of observations are sufficient for ±5% accuracy with 95% confidence limit. Indicate the minimum no of observations required.

Time (x)	4	5	6	7	8
frequency (f)	10	5	10	10	5

Sol

x	f	x^2	fx	fx^2
4	10	16	40	160
5	5	25	25	125
6	10	36	60	360
7	10	49	70	490
8	5	64	40	320
	$n = \Sigma f = 40$		$\Sigma fx = 235$	$\Sigma fx^2 = 1455$

$$N = \left[\frac{40 \sqrt{n \Sigma f x^2 - (\Sigma f x)^2}}{\Sigma (f x)} \right]^2$$

$$\therefore \left[\frac{40 \sqrt{40 \ 1455 - (235)^2}}{235} \right]^2$$

$$N = 86$$

(15)

(12)

(c) Check whether the no of observations is adequate for ±5 percent accuracy & 95 percent Confidence limit. If

(a) the no of observations of workers working = 4000

b) the no of observation of workers idle = 1000

c) total observations (n) = 5000

$$p = \frac{\text{Observations of idle workers}}{\text{Total no of observations}}$$

$$p = \frac{1000}{5000}$$

$$p = 0.20$$

$$S \times p = 2\sqrt{\frac{p(1-p)}{n}}$$

$$S \times 0.2 = 2\sqrt{\frac{0.2(1-0.2)}{5000}}$$

$$S \times 0.2 = 0.000032$$

$$S = 0.00016$$

$S = \pm 5\% = 0.05$, S value is lower than the level of accuracy, the data is sufficient.

Standard time calculations :-

The following is the formula used for determining the standard time when work sampling data is used.

$$\text{Standard time} = \frac{a \times b \times c}{d} + \text{Allowances}$$

where a = total working time (or) study time in minutes.

$$b = \frac{\% \text{ of working time}}{100}$$

$$c = \frac{\text{average performance rating}}{100}$$

d = total production during the observation period.

(1) An operator was kept under observation for five days. He was found working on 400 occasions & obstaining idle 100 times. He produced 100 jobs during these days. The observation per day was 5 hours only & the total no of observations were 500. Take 120 as the performance rating for the operator & 30% Allowance. Calculate the standard time.

$$\text{Standard time} = \frac{a \times b \times c}{d} + \text{Allowances}$$

Given data

$$\text{Total working time} = 5 \text{ days} \times 5 \text{ hours} \times 60 \text{ minutes}$$
$$= 1500 \text{ minutes.}$$

how to proceed with the job.

$$\text{percent waiting} = \frac{\text{No of observations for waiting}}{\text{total observations}} \times 100$$

$$= \frac{400}{500} \times 100$$

$$= 80$$

$$= \frac{1500 \times \frac{80}{100} \times \frac{130}{100}}{100} \times \frac{130}{100}$$

$$= \frac{1500 \times 0.8 \times 1.3}{100} \times 1.3$$

Std time = 20.28 minutes

(2) To determine the standard time of a particular work, five operators were kept under observation by a work sampling study group. The performance rating & the no of times the workers were found waiting each day were noted as given below:

Operation No	performance rating	No of times found waiting / % of working time				
		Jan 1 x_1	Jan 2 x_2	Jan 3 x_3	Jan 4 x_4	Jan 5 x_5
1	120	5	6	4	5	4
2	110	8	7	7	5	8
3	130	16	11	9	10	10
4	100	12	11	8	7	9
5	120	6	8	12	11	9

...ood to proceed with the job.

The total No of observations each day were 100. The No of times workers were found idle in their respective work places:

Date	Jan 1	Jan 2	Jan 3	Jan 4	Jan 5
No of times	5	7	6	8	7

The total production during 5 days = 3000 units

The working hours in a day = 8

Calculate the standard time for the job considering 30% of allowance.

Solution:-

Let us first find out the total no of observations of working operators.

	Jan 1	Jan 2	Jan 3	Jan 4	Jan 5
No of observations	100	100	100	100	100
No of times found idle	5	7	6	8	7
No of times found working	95	93	94	92	93

Total : 500

33

467

...ow to proceed with the job.

b = % of working time $= \frac{467}{500} \times 100 = 93.4$

$$b = \frac{\text{\% of working time}}{100}$$

$$b = \frac{93.4}{100}$$

$$b = 0.934$$

a = Total working time

a = No of operators × daily hours of work × No of days × 60 minutes per hour

$$a = 5 \times 8 \times 5 \times 60$$

$$a = 12000 \text{ minutes}$$

Average performance rate

operator No. → performance Rating × [Sum of No of times of found working]

operator 1 = $120 \times (5+6+4+5+4) = 2880$

2 = $110 \times (8+7+7+5+8) = 3850$

3 = $130 \times (10+11+9+10+10) = 6500$

4 = $100 \times (12+11+8+7+9) = 4700$

5 = $120 \times (6+8+12+11+9) = 5520$

$$\frac{23450}{5} =$$

how to proceed with the job.

Total of all the operators

Operator No-1 $5+6+4+5+4 = 24$

" 2 $8+7+7+5+8 = 35$

" 3 $10+11+9+10+10 = 50$

" 4 $12+11+8+7+9 = 47$

" 5 $6+8+12+11+9 = 46$

202

$\frac{202}{5} =$

Average performance Rating =

$C = \frac{\text{Average performance Rating}}{100}$

C :=

$d = 3000$ Allowances $= \frac{130}{100} = 0.13$

$= \frac{12000 \times \frac{93.4}{100} \times \frac{116.08}{100}}{3000} * \frac{130}{100}$

Standard time = 5.63 minutes.

Performance Rating :-

In the process of standard time, performance Rating has the most important role. while recording the time, it is necessary to know what kind of performance the operator is putting in.

"It is that process during which the

time study engineer compares the performance of the operator under observation with the observer's own concept of rideal or proper performance".

The performance Rating Factor is used to convert observed time in to Normal time.

$$\text{Normal time} = \text{Observed time} \times \frac{\text{Performance level of worker}}{\text{Standard performance level}}$$

$$\eta \text{ (Efficiency)} = \frac{\text{observed performance}}{\text{Normal performance}} \times 100.$$

Different methods of performance Rating :-

(1) Speed Rating
(2) Skill and Effort Rating
(3) Synthetic Rating
(4) objective Rating
(5) Westing house System Rating
(6) Physiological evaluation of performance level.

(1) Speed Rating :-

In Speed Rating, the speed of the movements of a worker is the only factor.

The time study engineer observes the speed of the movements of the worker against a standard

expected speed and he notes the relationship between them as a rating factor.

$$\text{Normal time} = \text{Observed time} \times \frac{\text{Worker's speed}}{\text{Speed expected from him}}$$

(ii) Skill and effort Rating :-

In this system, the time study engineer observes and judges how fast the operator performs the motions involved (not the movements the operator is using) and also his skill. Hence is it called as "Skill and effort rating".

(iii) Synthetic Rating :-

In this method, performance of the worker is tested using the values also known by P.M.T.S (predetermined motion time standards).

Procedure in this method is as follows :

Conduct time study in the usual manner for various elements and determine average time.

Ex:- Let the average time values of different elements be 0.10 minutes, 0.15 minutes, 0.20 minutes.

for the same elements Let PMTS values be 0.13 min, 0.19 min, 0.26 min.

Performance Rating = $\frac{\text{PMTS value for the element}}{\text{Average of Actual time values for same element.}}$

. Factor

$= \frac{0.13}{0.10} \times 100 = 130\%$.

$\frac{0.19}{0.15} \times 100 = 127\%$

$\frac{0.26}{0.20} \times 100 = 130\%$.

Average Rating factor $= \frac{130+127+130}{3} = 129\%$

(iv) Westing House System of Rating:-

A four factor system of performance rating was developed at westing house, the four factors are

Skill ; effort; conditions; consistency.

Now the time study engineer obtains the average or representative time. Also the worker is watched while working and he is given values for the four factors from the table.

. The average time obtained from time study is normalised by applying the sum of ratings of the four factors. The table is as follows:

Skill	Effort	Conditions	Consistency
Super.	Excessive	Ideal	Perfect
$A_1 = +0.15$	$A_1 = +0.13$	$A = +0.96$	$A = +0.04$
$A_2 = +0.13$	$A_2 = +0.12$		

Excellent	Excellent	Excellent	Excellent
$B_1 = +0.11$	$B_1 = +0.10$	$B = +0.04$	$B = +0.03$
$B_2 = +0.08$	$B_2 = +0.08$		
Good	Good	Good	Good
$C_1 = +0.06$	$C_1 = +0.05$	$C = +0.00$	$C = +0.00$
$C_2 = +0.03$	$C_2 = +0.02$		
Fair	Fair	Fair	Fair
$E_1 = -0.05$	$E_1 = -0.04$	$E = -0.03$	$E = -0.02$
$E_2 = -0.10$	$E_2 = -0.08$		
Poor	Poor	Poor	Poor
$F_1 = -0.16$	$F_1 = -0.12$	$F = -0.07$	$F = -0.04$
$F_2 = -0.22$	$F_2 = -0.17$		

Ex:- Let average time = 0.95 minutes

Good skill = +0.06

Excellent efforts = +0.10

Good conditions = +0.02

Good Consistenly = +0.01

Algebric Sum = +0.19

Worker is 19% above Average [Algebric sum = +ve

Note:- Suppose if worker gets Negative Algebraic sum, he is considered as below Average.

Allowances :- [Extra time provided for the worker, it is called Allowances]

It is obvious that any worker will not be able to work through out the day without any interruptions. The operator requires some time for his personal needs, rest etc and this time is provided to him by means of allowances

Following are the types of allowances to be considered depending on the situation.

(i) Relaxation Allowance
   a) personal Allowance
   b) Fatigue "
(ii) Contigency Allowance
(iii) Special "
(iv) Interference "
(v) process "

(i) Relaxation Allowance :-

This allowance depends on the nature of job. This allowance is divided into two categories namely

a) personal Allowance b) Fatigue Allowance.

(a) <u>personal Allowance</u> :-

A worker cannot work continuously like a machine. He has to attend his personal needs such as water, etc.

Hence the some time (allowance) has to be given to the worker for this purpose and it is generally taken to be 5 to 7% of average time.

(b) Fatigue Allowance :-

A worker is affected physiologically and psychologically because of carrying out a work. Due to this, fatigue is induced in him. Excessive Fatigue will have a Negative effective on the performance of the worker.

In order to overcome fatigue incurred during work the worker has to be provided with a fatigue allowance which is normally 4% of the average time.

The Fatigue allowance has two parts namely (i) Constant part (ii) Variable part.

Constant part of the fatigue allowance is the basic minimum fatigue for a worker seated and engaged in light work under ideal working conditions. ie 4%.

(ii) The variable part of fatigue allowance is added when the working conditions are severe (that is not ideal). It is based on factors which vary with working conditions such as standing (2%) Foot (10 to 2 Visual strain (4 to 8%) Mental strain, noise, vibrations etc.

(iii) Contigency Allowance :-

There are infrequent and irregular portions of a work of delays which are not possible to be measured correctly and economically.

An Allowance of time which is usually less than 5% is provided for this purpose and is called Contigency Allowance.

(ii) Special Allowance :-

These allowances are a policy matter of the managem There are certain activities which normally are not a part of the operation cycle but are important for satisfactory performance of work.

Some of the examples of such activities are setting a machine, cleaning, tool changing and regrinding etc.

An allowance provided to take care of such activiti is termed as special allowance.

(iv) Interference Allowance :-

When one worker is attending to more than one machine, one or more machines may stop while he is attending another machine.

i.e Interference is the time for which one or more

machines stop while the worker is occupied with the work on other machines.

Machine stoppage may be random and in this case the allowance provided is termed as "Random interference allowance".

Ex:- A Textile yarn winding machine will stop immediately when the yarn breaks. Here the machin stops due to a random cause and hence random interference allowance is provided.

Therbligs

Sr.No	Symbol	Name (Abbreviation)	Description.
1.		Search (Sh.)	Locate an article.
2.		Find (F)	It is mental reaction at the end of search, when the object has been found.
3.		Select (St)	The choice of one object from the lot.
4.		Grasp (G)	Hold of the object
5.		Hold (H)	Prolonged grasp of the object.
6.		Transport loaded (TL)	Movement of articles from one place to another place in hand.
7.		Position (P)	Placing the article in a definite location.
8.		Assemble (A)	Putting parts together, so that it may become an integral part.
9.		Use (U)	Causing a device to perform its function.
10		Dissamble (DA)	Seperating one object from an assembly.
11.		Inspect (I)	Examine standard size, shape etc
12.		Preposition (PP)	placing an article ready for use.
13.		Release load (RL)	Releasing the object at desired place.
14.		Transport empty (TE)	Moving empty hand for recieving an object.
15.		Rest (R)	Take rest (or) pause to overcome fatigue.
16.		Unavoidable Delay (UD)	Delay which is beyond the control of operator.
17.		Avoidable Delay (AD)	Delay which is within operator's control
18.		Plan (Pn)	It is a mental action, to plan, how to proceed with the job.

UNIT-VI

Project Management :-

It is a combination of all related activities which may be executed in a certain sequence order before entire task is completed.

→ It is used for planning, controlling, scheduling.

⇒ Introduction ; Literature survey; methods, Results-proj ba

Network Analysis :-

It is a graphical representation of a project plan showing inter relationships of various activities.

→ It is to represent by lines & circles.

→ Two Techniques are PERT, CPM.

Basic Network Terminology :-

Activity :- It is a task or Job of work, which takes time & resources. Represented by ⟶.

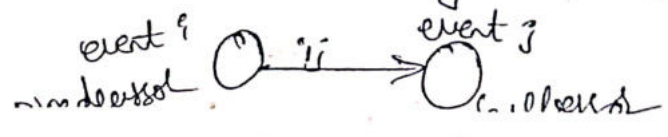
Head of arrow indicates where task ends & tail where task begins.

Event :- This is a point in time & indicates the start or end of an activity. Represented by circle or node.

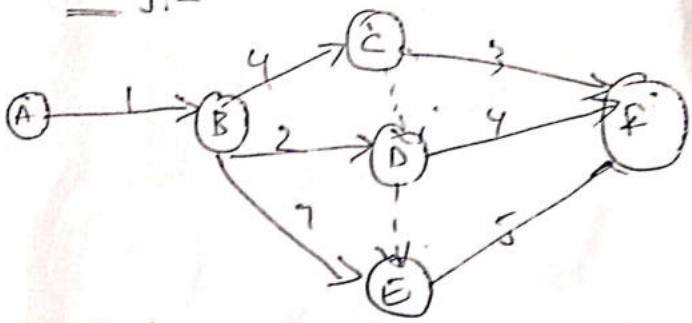
→ The event from which an arrow comes out is called predecessor event & denoted by event i

→ The event from which arrow gets is called successor denoted by event j.

→ The arrow connecting these two events is called activity ij.



Dummy Activity:-



It is an activity drawn to show clear & logical dependencies b/w activities so as not to violate the rules for drawing n/w. It does not consume res ources. Represented by arrow dotted lines ------>.

Rules for drawing Network:-

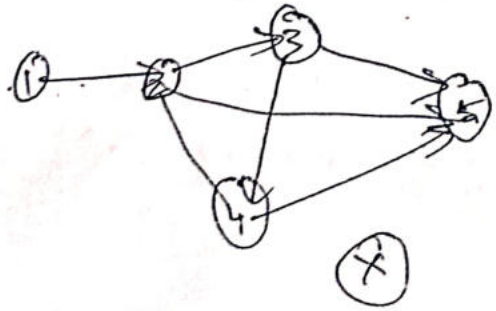
1) A Complete network should have only one point of entry event & only one point of exit event.

2) Every activity must have one preceding (i,j) tail event & one succeeding or head event. Note that many activities may use the same tail event & may use the head event.

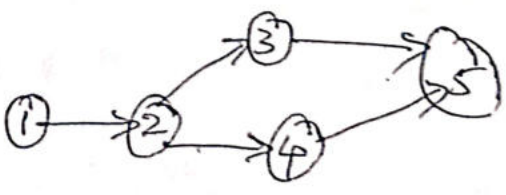
3) No Activity Can start until its tail event is reached.

4) An event is not Complete until all activities leading in to it are Complete.

→ An arrow should always be straight, not Curved & read from left to right.

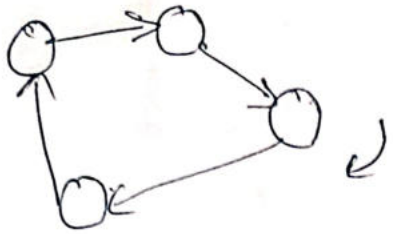


(X)

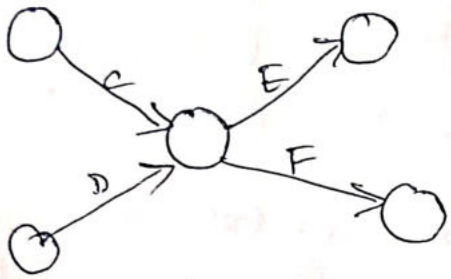


(✓)

5 Arrow cannot go backward as shown in fig.



→ We dummy activities when it is required to be minimized in N/w.



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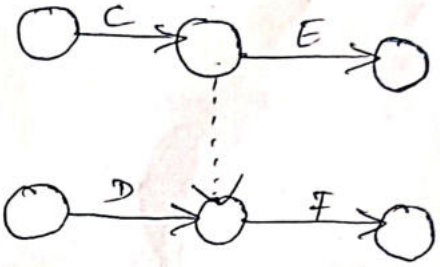
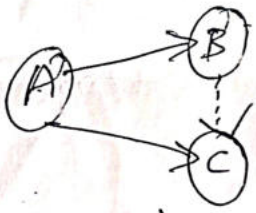


(✓)

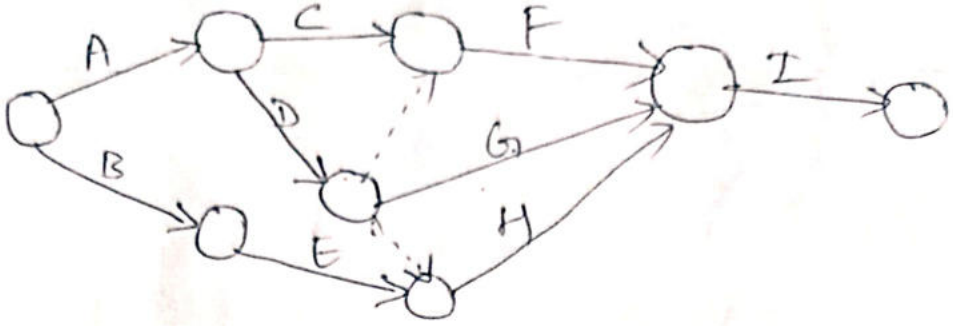
(X)



(✓)

① The following activities & logical sequence is given below. draw N/w.

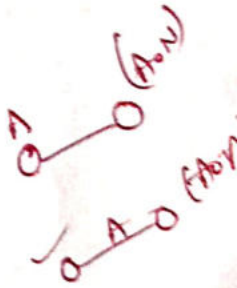
Activity	Preceding Activity
A	—
B	—
C	A
D	A
E	B
F	C, D
G	D
H	D, E
I	F, G, H.

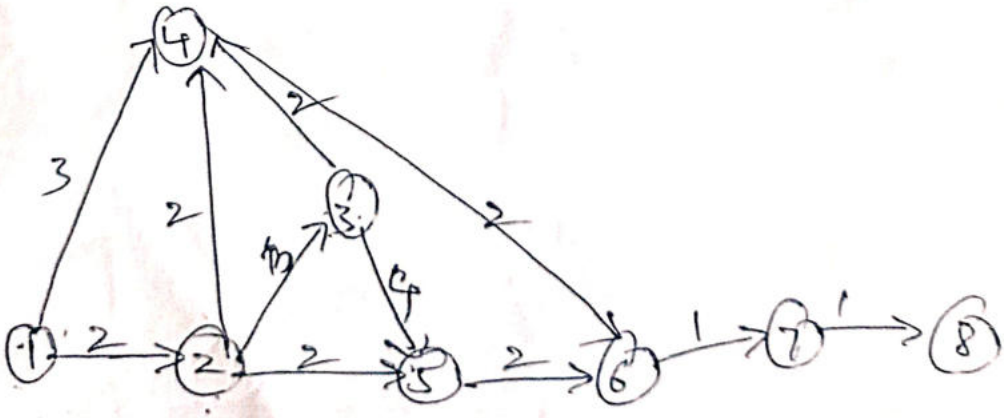


(2)

Activity	Time duration
1-2	2
1-4	3
2-4	2
2-3	3
3-4	4
2-5	2
3-5	4
5-6	2
4-6	2
6-7	1
7-8	1

AOA
AON





used for research & development projects

PERT

1) Critical path is determined by event oriented.
It is event-oriented.

2) It is based on 3 time estimates i) optimistic ii) most likely iii) pessimistic.
PERT is a technique for evaluating the probability of completing the project.

3) Time, in PERT, is not related to costs. hence it is more applied where pressure on the end results is meaningless, as in the case of R&D, or defence projects.

4) PERT terminology involves Network diagram, event, slacks...

5) It assumes that all the resources [men, money, materials, machines] are available as & when required.

6) It deals with probabilistic N/w.
-> PERT deals with beta distribution.

→ used for repetition projects such as Construction jobs. ①

CPM

→ CP is activity oriented.

1) It is activity oriented.

2) It is deterministic. here, time estimates are based on past data.

3) here time is related to costs. It can be advantageously applied where there is a need to complete the projects within a given dead line.

4) CPM terminology involves arrow diagram, nodes, float.
→ deal with deterministic N/w.

5) It is more realistic.
It considers the constraints on resources.
It provides information about implications of crashing the duration of N/w.
→ normal distribution

CPM :- (Critical path method) :-

Activity Time estimations :-

Methods in scheduling computation :-

The starting & finishing time of activities can be calculated using following two methods namely.

a) Forward pass method

b) Backward " "

a) Forward pass method :-

In forward pass method, Computations (Calculations) proceed from initial event to final (Terminal) event here two terms are defined namely.

i) Early start time

ii) Early finish time

i) EST :- It is the earliest time at which an activity can be started.

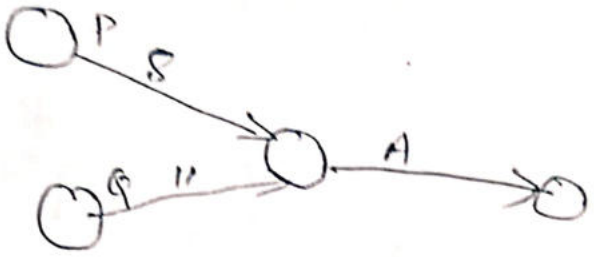
ii) EFT :- It is the earliest completion time of an activity.

Rules in CPM :-

1) The initial project event is assumed to occur at time zero

The early start time of an activity is taken to the maximum early finish time of its immediate predecessors.

Ex:-



$$EST = \text{maximum } EF[A, 9]$$
$$= \max[8, 11]$$
$$= 11$$

3) The EFT of an activity is sum of early EST & duration of an activity.

$$EFT = EST + \text{Duration}.$$

b) Backward pass method:-

In BPM, computations (Calculations) proceed from find event to initial event.

i) Late start time

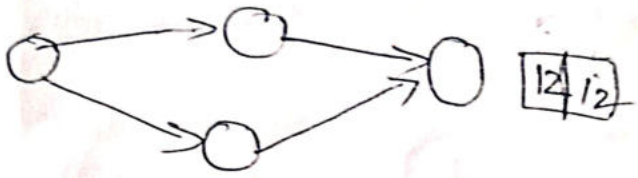
ii) Late finish time.

i) LST:- It is the latest time at which an activity can be started.

ii) LFT:- It is the latest time at which an activity can be completed.

- Rules in PM:- (Backward pass method)

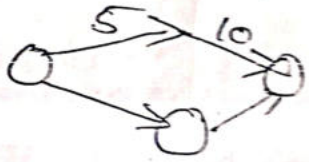
i) The latest allowable finish time of the project final event is set equal to either an arbitary time.



EST = LFT.

ii) The LFT of an activity is equal to the minimum LST of its successors.

LFT = min LS(successors)
= min(5, 10)
= 5.



iii) LST of an activity is equal to the LFT of it duration.

LST = LFT - duration.

Float (or) slack:

Slack is with reference to an event.

float " " " to activity.

In other words, slack is used with PERT.

float " " CPM.

It may be float or slack, it means spare time, a margin of extra time over & above its duration, which a non critical activity can consume without delaying the project.

Float is the difference b/w time available for completing an activity & time necessary to complete the same.

i) Total float :- It is the additional time which a non critical activity can consume without increasing the project duration, however total float may effects the floats in previous & subsequent activities.

T.f :) LFT - EFT (or) LST - EST

ii) $TL = (LFT)_{2nd} - (EST)_{1st} - \text{duration}.$

ii) Free float :- If all non critical activities start as easly as possible, surplus time is the free float.

If used, it does not change the float in later activities. otherwords if an activity is delayed by the free float period, succeeding activity will not be delayed.

$$FF = (EST)_{2nd} - (EST)_{1st} - \text{duration}.$$

F.f :) T.f - H.d

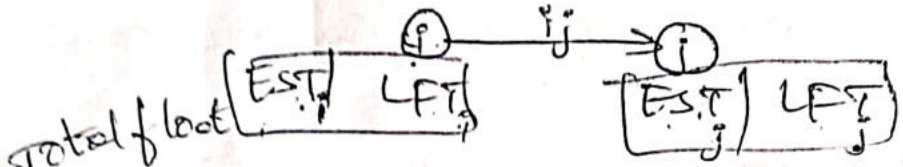
iii) Independent float :-

It refers to the time by which an activity can expand without affecting any other preceding & succeeding activity.

I.f :) f.f - T.d

It is the earliest date of succeeding event minus latest date of preceding event minus activity duration.

$$TF = (EST)_{2nd} - (LFT)_{1st} - \text{duration}.$$



TF :- Start present work as early as possible — start network as late as possible.

$$TF = (LFT)_{2nd} - (EST)_{1st} - \text{duration}$$

LFT - EFT

Free float

FF :- Start present work — Next work as early as possible.

T.F - head event slack

$$FF = (EST)_{2nd} - (EST)_{1st} - \text{duration}.$$

Independent float

IF :- present work as late as possible — start next work as early as possible.

F.F - Tail event slack

$$IF = (EST)_{2nd} - (LFT)_{1st} - \text{duration}.$$

TF :- This is the amount of spare time available for an activity without delaying the whole project.

FF :- This is the amount of spare time available for an activity without delaying the next activity.

3. The maintenance of a machine consists of ten jobs (Activities) The precedence relationship of these Jobs have to be listed with the help of their node numbers.

Job	1-2	1-3	1-4	2-5	3-6	4-7	3-7	5-8
duration (days)	2	2	2	4	5	4	8	2

6-8	7-9	9-6	8-9
4	5	4	3.

i) draw an arrow diagram (or) Network for the project.

ii) Calculate critical path?

T.F = EST - EST (or) LFT - EFT

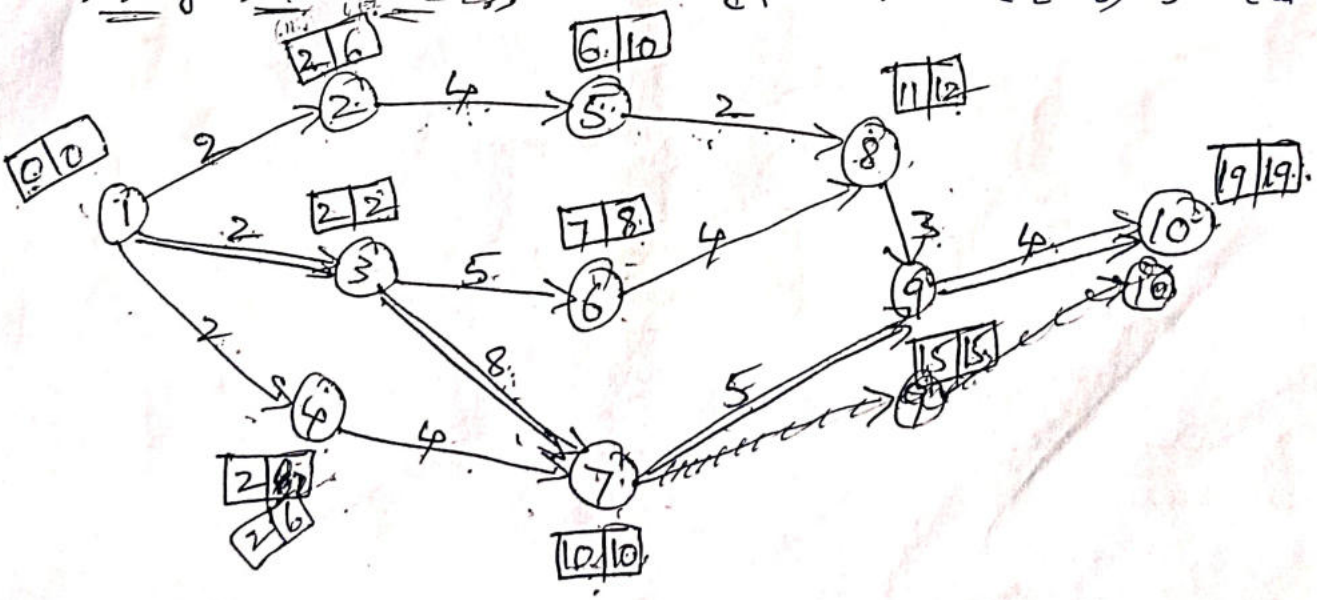
F.F = T.F - Head event slack

T.F - $(T_L - T_E)$ for head event

I.F = F.F - $(T_L - T_E)$ for tail event

Project Network:-

Early start times;



Early start time :-

Event ① = 0

event 2 :-

1-2 = 2

event 3 :-

1-3 = 2

event 4 :-

1-4 = 2

event 5 :-

1-2-5 = 2+4 = 6

event 6 :-

1-3-6 = 2+5 = 7

event 7 :-

1-3-7 = 2+8 = (10)

1-4-7 = 2+4 = 6

event 8 :-

1-2-5-8 = 2+4+2 = 8

1-3-6-8 = 2+5+4 = (11)

1-4-7-9 = 12

event 9 :-

1-2-5-8-9 = 2+4+2+3 = 11

1-3-6-8-9 = 2+5+4+3 = 1

1-3-7-9 = 2+8+5 = (15)

event 10 :-

1-2-5-8-9-10 = 2+4+2+3+4 = 15

1-3-6-8-9-10 = 2+5+4+3+4 = 18

1-4-7-9-10 = 2+4+5+4 = 15

1-3-7-9-10 = 2+8+5+4 = (19)

Late finish time :-

event 10 = 19

event 9 :-

10-9 = 19-4 = 15

event 8 :-

event 7 :-

10-9-7 = 19-4-5 = 10

event 6 :-

10-9-8-6 = 19-4-3-4 = 8

event 5:-

10-9-8-5 = 19-4-3-2 = 10

event 4:-

10-9-7-4 = 19-4-5-4 = 6

event 3:-

10-9-7-3 = 19-4-5-8 = (2)

10-9-8-6-3 = 19-4-3-4-5 = 3

event 2:-

10-9-8-5-2 = 19-4-3-2-4 = 6

event 1:-

10-9-8-5-2-1 = 19-4-3-2-4-2 = 4

10-9-8-6-3-1 = 19-4-4-5-2 = 4

10-9-7-3-1 = 19-4-5-8-2 = (8)

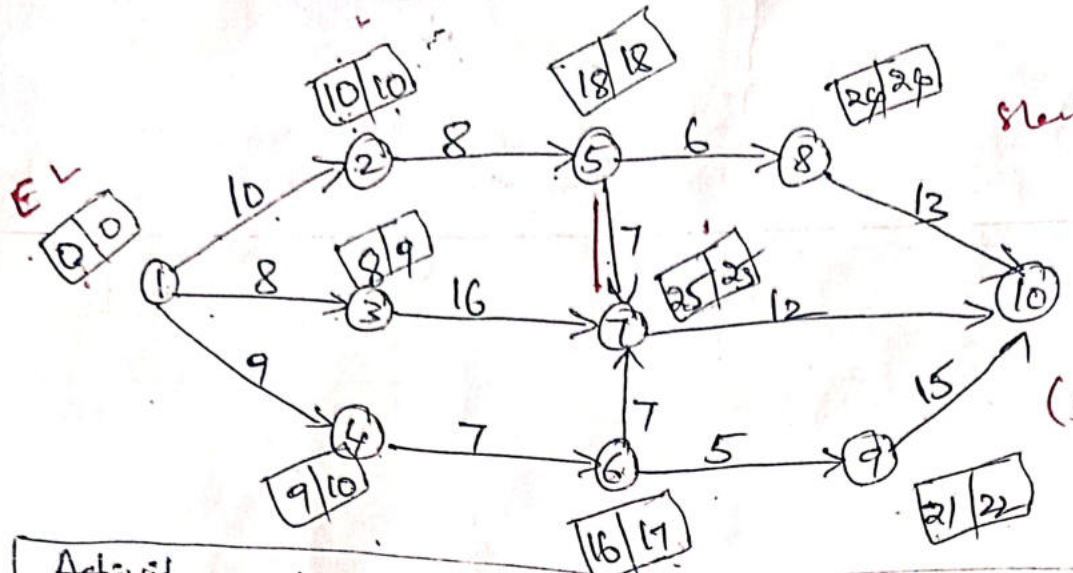
10-9-7-4-1 = 19-4-5-4-2 = 4

Critical path:-

1-3-7-9-10 = 2+8+5+4 = 19.

2) find out critical path, EST, LFT, EFT, LST, TF, IF, FF.

Activity	duration
1-2	10
1-3	8
1-4	9
2-5	8
4-6	7
3-7	16
5-7	7
6-7	7
5-8	6
6-9	5
7-10	12
8-10	13
9-10	15



PERT

Min ← B.P.C

(Burnal) f.P.C → Max

Merge

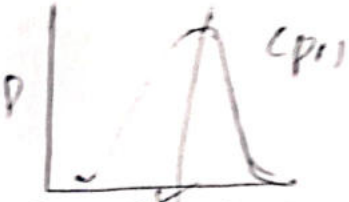
Activity (i-j)	D	EST (i)	LFT (j)	EFT: EST+D	LST: LFT-D	TF: S-E-D	FF: S-E-D	IF: E-L
1-2	10	0	10	10	0	0	0	0
1-3	8	0	9	8	1	1	0	0
1-4	9	0	10	9	1	1	0	0
2-5	8	10	18	18	10	0	0	0
4-6	7	9	17	16	10	1	0	0
3-7	16	8	25	24	9	1	1	0
5-7	7	18	25	25	18	0	0	0
6-7	7	16	25	23	18	2	2	0
5-8	6	18	24	24	18	0	0	0
6-9	5	16	22	21	17	1	0	1
7-10	12	25	37	37	25	0	0	0
8-10	13	24	37	37	24	0	0	0
9-10	15	21	37	36	22	1	1	0

TF :- $(LFT)_{2nd} - (EST)_{1st} - \text{duration}$.

1-2. $= 10 - 0 - 10 = 0$

FF $= (EST)_{2nd} - (EST)_{1st} - \text{Duration} = 10 - 0 - 10 = 0$

(8)



PERT :- [Program Evaluation Review Technique]

(9)

Time estimates :-

i) optimistic time :- (to)

It refers to the minimum time the activity takes, assuming that there will not be any hindrances, such as delay, setback .... denoted by 'to'.

ii) pessimistic time :- (tp)

This is the maximum time it could take to complete the job.

Basing the major disturbances such as labour strike, setbacks & other delays. are considered here. denoted by 'tp'.

(iii) most likely time (tm) :- α=(tl)

This is the time estimate, which lies in btw the optimistic & pessimistic time estimates.

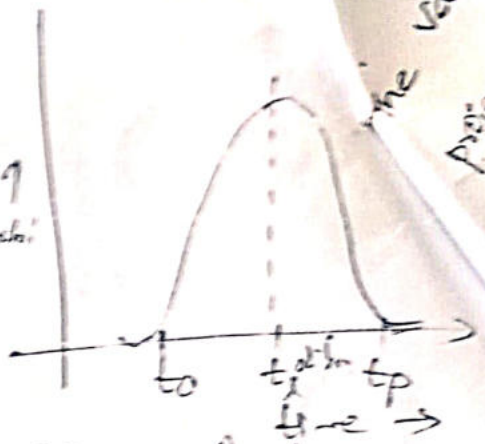
Average time estimate :- (te) :- [expected time estimate]

The avg of three time estimates. is equal to the aggregate of one-sixth of optimistic, two thirds of most likely, one-sixth of pessimistic time

denoted by 'te'.

$$t_e = \frac{1}{6} t_o + \frac{2}{3} t_m + \frac{1}{6} t_p$$

$$\boxed{t_e = \frac{t_o + 4t_m + t_p}{6}}$$



This eq is very significant in PERT analysis.

→ If an activity is likely to take 20 minutes of optimistic time, 30 mins of most likely, 40 mins of pessimistic time estimate, what is the average time estimate?

$$t_e = \frac{20 + 4 \times 30 + 40}{6} = 30 \text{ minutes}$$

Range, Standard deviation & Variance:-

Range:- The range is equal to the difference b/w the pessimistic time (t_p) & optimistic time (t_o),

$$\text{Range} = t_p - t_o$$

Standard deviation:-

The standard deviation (σ) is equal to $= \frac{1}{6}$ of Range,

$$\sigma = \frac{t_p - t_o}{6}$$

Variance:-

Variance is equal to $\sigma^2 = \left(\frac{t_p - t_o}{6}\right)^2$

The various time estimates of activities involved in a project are given in table :-

Activities	1-2	1-3	2-4	2-3	3-4	3-5	4-6	5-6
to	2	4	2	2	0	3	6	1
tm	6	8	3	4	0	6	10	3
tp	10	12	4	6	0	9	14	5

i) determine the expected Completion time of the project.

ii) determine Variance, standard deviation of the project.

iii) determine probability of completing the project within 23 days ?

iv) what is the probability that jobs on next next critical path will be completed by due date of 42 days?

$$t_e = \frac{to + 4tm + tp}{6}$$

$te(1-2) = \frac{2+4\times6+10}{6} = 6$

$te(1-3) = 8$

$te(2-4) = 3$

$te(2-3) = 4$

$te(3-4) = 0$

$te(3-5) = 6$

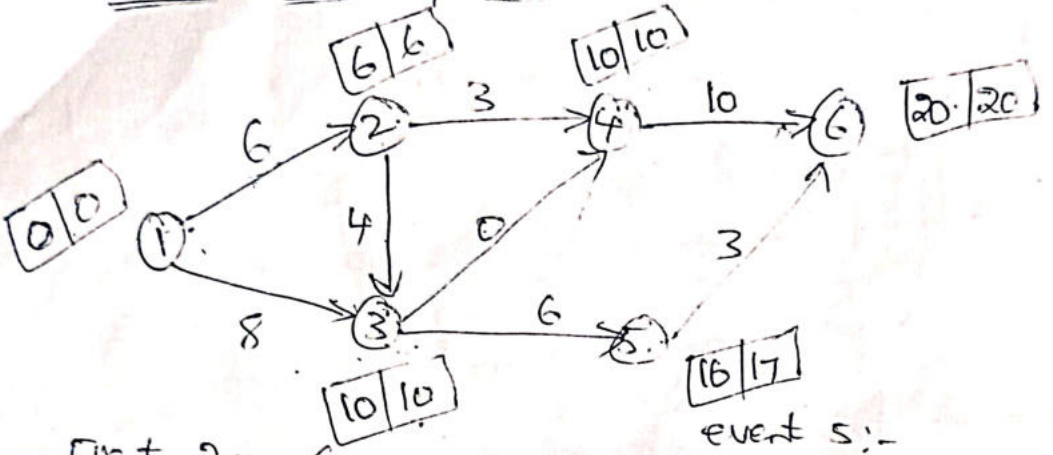
$te(4-6) = 10$

$te(5-6) = 3$

v) what is your estimate on the entire project being completed by due date ?

Activity	1-2	1-3	2-4	2-3	3-4	3-5	4-6	5-6
Expected time (te)	6	8	3	4	0	6	10	3

Network with expected time (te):-



Event 2:- 6

event 3:- 1-3 = 8

1-2-3 = 10

event 4:- 1-2-4 = 6+3 = 9

1-3-4 = 8

1-2-3-4 = 6+4 = 10

event 5:-

1-3-5 = 8+6 = 14

1-2-3-5 = 6+4+6 = 16

event 6:-

1-2-4-6 = 6+3+10 = 19

1-2-3-4-6 = 6+4+10 = 20

LFT:

Event 6:- 20

event 5:- 20-3 = 17

event 4:- 20-10 = 10

event 3:-

6-5-3 = 20-3-6 = 11

6-4-3 = 20-10 = 10

event 2:-

6-4-2 = 20-10-3 = 7

6-4-3-2 = 20-10-4 = 6

6-5-3-2 = 20-3-6-4 = 7

event 1:-

0

1-2-4-6 => 6+3+10 = 19

1-2-3-4-6 => 6+4+10 = 20

Standard deviation:-

$$\sigma = \frac{t_p - t_o}{6}$$

$\sigma(1-2) = \frac{10-2}{6} = \frac{8}{6} = 1.33$

$\sigma(1-3) = \frac{12-4}{6} = \frac{8}{6} = 1.33$

$\sigma(2-4) = \frac{4-2}{6} = \frac{2}{6} = 0.33$

$\sigma(2-3) = \frac{6-2}{6} = \frac{4}{6} = 0.66$

$\sigma(3-4) = 0$

$\sigma(3-5) = \frac{9-3}{6} = \frac{6}{6} = 1$

$\sigma(4-6) = \frac{14-6}{6} = \frac{8}{6} = 1.33$

$\sigma(5-6) = \frac{5-1}{6} = \frac{4}{6} = 0.33$

Variance:-

$$\sigma^2 = \left(\frac{t_p - t_o}{6}\right)^2$$

1-2-3-4-6 (critical path) $= \sigma^2(1-2) + \sigma^2(2-3) + \sigma^2(3-4) + \sigma^2(4-6)$

$= (1.33)^2 + (0.66)^2 + 0^2 + (1.33)^2$

$\sigma^2 = 3.9734$

$\sigma = 1.993$

Next most critical path

1-2-4-6 $= \sigma^2(1-2) + \sigma^2(2-4) + \sigma^2(4-6)$

$= (1.33)^2 + (0.33)^2 + (1.33)^2$

$= 3.6467$

$\sigma = 1.9096$

3) Probability of completing the project in 23 days?

Normal deviate $Z = \frac{D - T_e}{\sigma}$ or $\frac{T - T_{cp}}{\sigma_{cp}}$ N.O.T

D = due date t_e = expected time, σ = std deviation.

$= \frac{23 - 20}{1.993} = 1.505$

In table 1.5 to 0.5 delegate values; 0.93999 ~~0.9418~~

4) Next most critical path

$Z = \frac{D - T_E}{\sigma}$

$Z = \frac{~~...~~ - 19}{1.999} = 12.048$ ~~...~~ > 3

P = 99%.

table, z = ?

5) Total probability = probability of critical path × probability of next critical path.

$= 0.9418 \times 0.99$

$= 0.932$.

probability of completing the project within given time = 93.23%

" " Not " " $= 100 - 93.23$

$= 6.77\%$

→ The Jobs of a project with the respective time estimates are given

Jobs	1-2	1-6	2-3	2-4	3-5	4-5	6-7	5-8	7-8
t_o	3	2	6	2	5	3	3	1	4
t_m	6	5	12	5	11	6	9	4	19
t_p	15	14	30	8	17	15	27	7	28

i) draw the network.

ii) Calculate variance of each job, standard deviation.

iii) what is the probability that the jobs on the critical path will be completed by the due date 42 days?

Crashing problem:-

1) From the following particulars.

1) draw the N/w.

2) Calculate the easliest expected time, latest starting time & identify critical path.

3) determine cost slope.

4) prepare a statement showing the different stages of crashing & corresponding cost estimates, assuming that the project has a fixed overhead cost of Rs 600 per day.

5) find out the optimum duration & cost for the project.

Jobs	Normal time (days)	Crash time	NC	CC
1-2	3	2	10,000	11,000
1-3	6	3	6000	8400
2-3	9	3	9000	12000
2-4	7	4	5200	7800
3-4	3	2	3000	3400

Activity	Preceding Activity	Time (Weeks)		cost (Rs)	
		Normal	crash	Normal	crash
A	—	6	4	5000	6200
B	—	4	2	3000	3900
C	A	7	6	6500	6800
D	A	3	2	4000	4500
E	B,C	5	3	8500	10,000

$$\text{cost slope} = \frac{\text{Crash cost} - \text{Normal cost}}{\text{Normal Time} - \text{crash Time}}$$

	Normal time(days)	Normal cost(Rs)	Crash time(days)	
1-2	3	10000	2	11,000
1-3	6	6000	3	8400
2-3	9	9000	3	12000
2-4	7	5000	4	7800
3-4	3	3000	2	3400