Operations Management - Revision Material

CMA Inter - Paper 09

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Operations Management

Operations Management is the management of that part of an organization that is responsible for producing goods and/or services. It refers to the administration of business practices to create the highest level of efficiency possible within an organization. It is concerned with converting material converting materials and labor into goods and services as efficiently as possible to maximize the profit of an organization.

Objectives of Operations Management;

1. Customer Service; The Operations Management must provide something to a specification which can satisfy the customer in terms cost and timing. Thus, primary objective can be satisfied by providing the 'right thing at the right price at the right time'. There are three aspects of Customer Service;
   a. Specification
   b. Cost , and
   c. Timing

: Aspects of Customer Service

Principal customer wants		
Principal function	**Primary consideration**	**Other consideration**
Manufacture	Goods of a given, requested or acceptable specification	Cost i.e. purchase price or cost of obtaining goods Timing, i.e. delivery delay from order or request to receipt of goods
Transport	Movement of a given, requested or acceptable specification	Cost, i.e. cost of movement, Timing ,i.e. (i) duration or time to move (ii) wait, or delay from requesting to its commencement
Supply	Goods of a given, requested or acceptable specification	Cost, that is purchase price or cost obtaining goods Timing, i.e. delivery delay from order or request to supply, to receipt of goods
Service	Treatment of a given, requested or acceptable specification	Cost, i.e. cost of treatment Timing, i.e. (i) Duration or timing required for treatment (ii) wait, or delay from requesting to its commencement

2. Resource Utilization; customer service must be provided with the achievement of effective operations through efficient use of resources. Inefficient use of resources or inadequate customer service leads to commercial failure of an operating system.

The twin objectives of operations management

The customer service objective.	**The resource utilization objective.**
To provide agreed/adequate levels of customer service (and hence customer satisfaction) by providing goods or services with the right specification, at the right cost and at the right time.	To achieve adequate levels of resource utilization (or productivity) e.g., to achieve agreed levels of utilization of materials, machines and labour.

Scope of Operations Management;

1. Location of facilities.
2. Plant layouts and Material Handling.
3. Product Design.
4. Process Design.
5. Production and Planning Control.
6. Quality Control.
7. Materials Management.
8. Maintenance Management.

Designing of Goods and Services; (Product Design)

A. Objectives of Product Design;
   1. The overall objective is profit generation in the long run.
   2. To achieve the desired product quality.
   3. To reduce the development time and cost to the minimum.
   4. To reduce the cost of the product.
   5. To ensure manufacturability (design for manufacturing and assembly).

B. Factors Influencing Product Design;
   a. Customer requirements;
   b. Convenience of the operator or user:
   c. Trade off between function and form:
   d. Types of materials used:
   e. Work methods and equipments:
   f. Cost/Price ratio:
   g. Product quality:
   h. Process capability:
   i. Effect on existing products:
   j. Packaging:

C. Characteristics of Good Product Design;
   1. Function or performance: what the customer expects the product to do to solve his/her problem or offer certain benefits leading to satisfaction
   2. Appearance or aesthetics: includes the style, colour, look, feel, etc. which appeals to the human sense and adds value to the product.
   3. Reliability: probability that a product will function for a specific time period without failure.
   4. Maintainability:
   5. Availability:
   6. Productibility: This refers to the ease of manufacture with minimum cost
   7. Simplification:
   8. Standardisation: Refers to the design activity that reduces variety among a group of products or parts.
   9. Specification
   10. Safety:

New Product Design; (Product Development);

A. The Origin of New Products;

Approaches to Product Design;

1. Designing for the Customer; One approach to getting the **voice of the customer** into the design specification of a product is **quality function deployment (QFD).**
2. Designing for Manufacture and Assembly (DFMA);
   a. **"over-the-wall approach";** "we design it, you build it"

Problems in this approach can be overcome by an approach known as **concurrent engineering** (or simultaneous engineering).

- ✓ Concurrent engineering means bringing design and manufacturing people together early in the design phase to simultaneously develop the product and processes for manufacturing the product.
- ✓ **Design for Manufacturing (DFM);** The term design for manufacturing is used to indicate the designing of products that are compatible with an organisation's capability
- ✓ **Design for Assembly (DFA);** Design for assembly focuses on reducing the number of parts in a product or on assembly methods and sequence that will be employed.

3. Designing for Ease of Production; Designing products for ease of production is a key way for manufacturers to be competitive in the world market. Three concepts which are closely associated to designing for ease of production are:
   a. **Specifications**; A Specification is a detailed description of a material, part or product, including physical measures such as dimensions, volume, weight etc.
   b. **Standardisation;** refers to design activity that reduces variety among a group of products or parts. This will result in higher volume for each product or part model which can lead to lower production costs, higher product quality and lower inventory and higher ease of automation.
   c. **Simplification;** Simplification of product design is the elimination of complex features so that the intended function is performed with reduced costs, higher quality and better customer satisfaction.
4. Designing for Quality; Building product quality into the product design is the first step in producing products of superior quality. This is known as **"quality of design".**
   - ➢ Quality of design refers to the quality specifications incorporated in the design. It consists of quality characteristics such as appearance, life, safety, maintenance and other features of the product

   Quality of Design is followed by Quality of Conformance;
   - ➢ Quality of conformance is the degree to which the product actually conforms to the design specification.

   Designing products for quality consists of three aspects of design
   a. Robust Design; A robust design is one that will perform as intended even if undesirable conditions occur either in production or in the field.
   b. Designing for Production; (for ease of manufacturer and assembly)
      - ✓ **Modular Design;**
      - ✓ **Designing for Automation**
   c. Designing for Reliability; probability that a product will function for a specific time period without failure.
5. Designing for Ergonomics; Poorly designed products may cause work-related accidents resulting in injuries to users. Hence, comfort, safety and ease of use for the users are becoming more important quality dimensions that have to be considered in product design. Human Factor Engineering or Ergonomics applies knowledge of human capabilities and limitations to the design of products and processes.
6. Designing for Environmental Protection; This includes designing products which are environmental friendly (e.g., Euro II automobile) known as green designs. Sometimes reaction to a social or environmental concern opens up a set of promising new design options.
7. Designing for Recycling; This approach to product design focuses on designing products so that raw materials such as plastics can be retrieved once the product has finished its useful life and scrapped. Recycling means recovering materials for further use. Recycling is done to achieve cost savings, and also to meet environmental concerns and regulations. Designing for recycling facilitates the recovery of materials and components in used products for reuse.
8. Designing for Disassembly; (DFD); This involves designing products which can be more easily taken apart or disassembled. It includes fewer parts and less material and using snap-fits where possible instead of screws, bolts and nuts.
9. Designing for Mass Customisation; It is a strategy of designing standardised products but incorporating some degree of customization in the final product. **Delayed differentiation** and **modular designs** are two tactics used to make mass customisation possible.
   a. **Delayed differentiation;** is the process of producing but not quite completing, a product, postponing completion until customer preferences or specifications are known.
   b. **Modular designs;** is a form of standardisation in which component parts are grouped into modules that are easily replaced or interchanged to produce varieties of the same basic product.
10. Computer Aided Design (CAD); CAD uses computer graphics for product design. A number of products such as printed circuit boards, transformers, automobile parts, aircraft parts etc. can be designed using CAD.

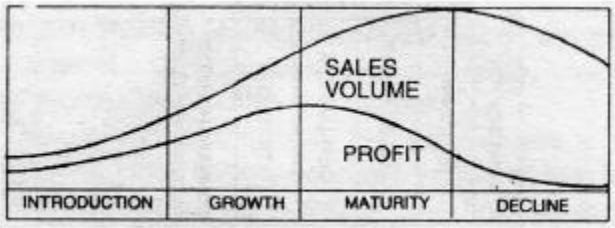
11. **Value Engineering/Value Analysis in Product Design:** Value engineering or value analysis is concerned with the improvement of design and specifications at various stages such as research, development, design and product development.

    Benefits;

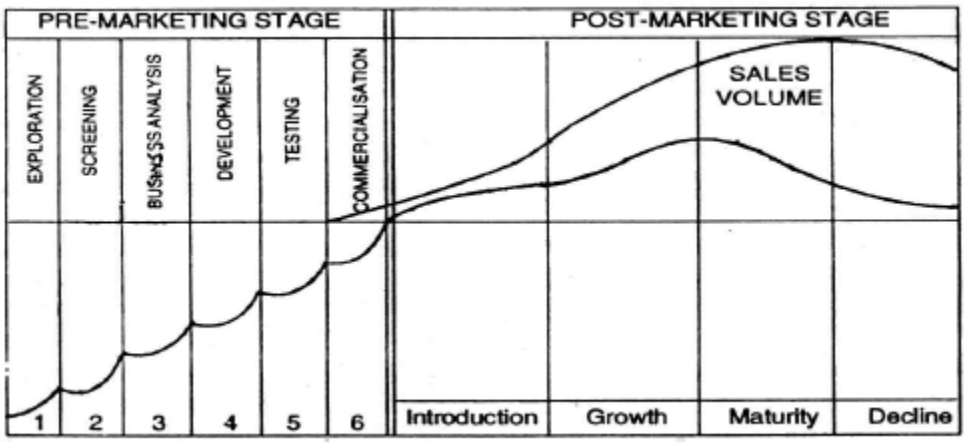
    a. Cost reduction.
    b. Less complex products.
    c. Use of standard parts/components.
    d. Improvement in functions of the product.
    e. Better job design and job safety.
    f. Better maintainability and serviceability.
    g. Robust design.

    Value engineering aims at cost reduction at equivalent performance. It can reduce costs to the extent of 15% to 70% without reducing quality. While value engineering focuses on preproduction design improvement, value analysis, a related technique seeks improvements during the production process. (Dec 2014)

B. Product Life Cycle;



: Product life Cycle.



The Full Life cycle of a Product from Its Exploration Stage to Decline Stage.

The life cycle is nothing more than the pattern of demand for a product over time. Not every product goes through every stage. In fact, many products never get past the introduction stage. The length of time a product spends in any one stage may vary differently. Some products move through the entire cycle in a very short period. **Repositioning** a product can lead to a new growth cycle. Repositioning is basically changing the image or perceived uses of the product.

Process Planning;

Process Planning and Process Design; A process is a sequence of activities that is intended to achieve some result, typically to create added value for the customers.

- ✓ A process converts inputs into outputs in a production system.
- ✓ It involves the use of organisation's resources to provide something of value

Process decisions involve many different choices in selecting human resources, equipment and machinery, and materials. Process decisions are strategic and can affect an organisation's ability to compete in the long run.

Types of Processes:

1. Conversion processes; converting the raw materials into finished products(converting iron ore into iron and then to steel). The conversion processes could be metallurgical or chemical or manufacturing or construction processes.
2. Manufacturing processes;
   - **a. Forming processes** include foundry processes (to produce castings) and other processes such as forging, stamping, embossing and spinning. These processes change the shape of the raw material (a metal) into the shape of the workpiece without removing or adding material.
   - **b. Machining processes** comprise metal removal operations such as turning, milling, drilling, grinding, shaping, planing, boring etc.
   - **c. Assembly processes** involve joining of parts or components to produce assemblies having specific functions.

Process Planning; (Dec 2014)Process planning is concerned with planning the conversion processes needed to convert the raw material into finished products. It consists of two parts:

1. Process Design; **Process Design** is concerned with the overall sequences of operations required to achieve the product specifications.
   - ✓ It specifies the type of work stations to be used
   - ✓ the machines and equipments necessary to carry out the operations
   - ✓ The sequence of operations are determined by
     a. the nature of the product,
     b. the materials used
     c. the quantities to be produced and (d) the existing physical layout of the plant.
2. Operations Design; **Operations Design** is concerned with the design of the individual manufacturing operation.
   - ✓ It examines the man-machine relationship in the manufacturing process.
   - ✓ Operations design must specify how much labour and machine time is required to produce each unit of the product.

Framework for Process Design; The process design is concerned with the following:

a. Characteristics of the product or service offered to the customers.
b. Expected volume of output.
c. Kinds of equipments and machines available in the firm.
d. Whether equipments and machines should be of special purpose or general purpose.
e. Cost of equipments and machines needed.
f. Kind of labour skills available, amount of labour available and their wage rates.
g. Expenditure to be incurred for manufacturing processes.'
h. Whether the process should be capital-intensive or labour-intensive.
i. Make or buy decision.
j. Method of handling materials economically.

Process Selection; Process selection refers to the way production of goods or services is organised.

- ✓ It is the basis for decisions regarding capacity planning, facilities (or plant) layout, equipments and design of work systems.
- ✓ Process selection is necessary when a firm takes up production of new products or services to be offered to the customers.

Three primary questions to be addressed before deciding on process selection are:

(i) How much variety of products or services will the system need to handle?

(ii) What degree of equipment flexibility will be needed?

(iii) What is the expected volume of output?

Process Strategy; A **process strategy** is an organisation's approach to process selection for the purpose of transforming resource inputs into goods and services (outputs)

- The objective of a process strategy is to find a way to produce goods and services that meet customer requirement and product specification (i.e., design specifications) within the constraints of cost and other managerial limitations

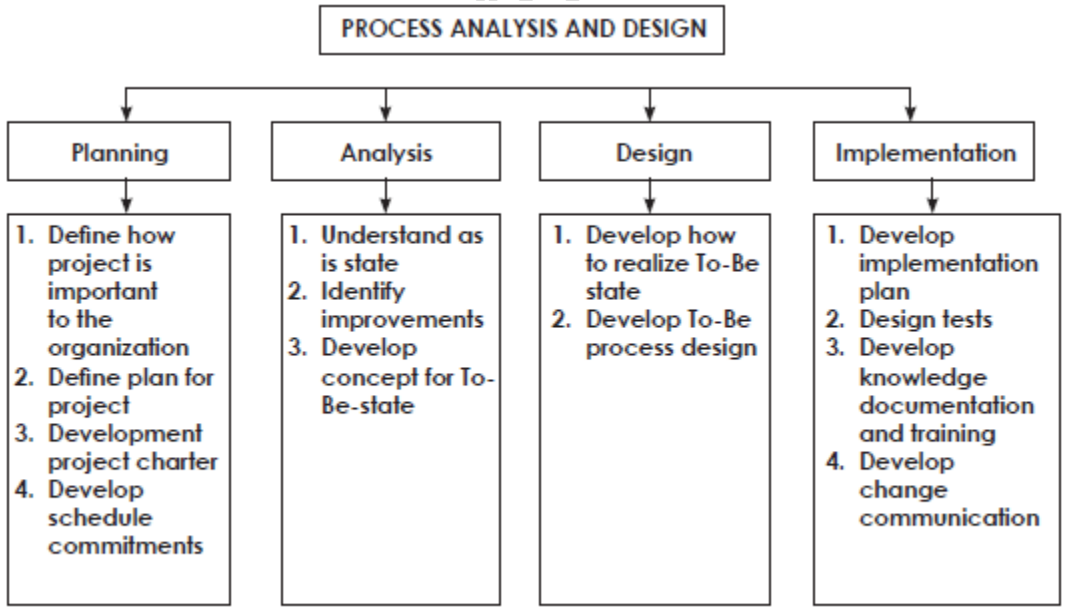
Key aspects in process strategy include:

a. Make or buy decisions
b. Capital intensity; refers to the mix of equipment and labour which will be used by the firm, and
c. Process flexibility; refers to the degree to which the system can be adjusted to changes in processing requirements due to such factors as changes in product or service design, changes in volume of products produced and changes in technology.

Three process strategies:

1. **Process Focus:;**
   - ✓ Each process is designed to perform a wide variety of activities and handle frequent changes. Such processes are called **intermittent processes**
2. **Repetitive Focus; A** repetitive process is a product oriented production process that uses modules. It falls between product focus and process focus. It uses modules which are parts or components prepared often in a continuous or mass production process.
   - ✓ A good example of repetitive process is the **assembly line** which is used for assembling automobiles and household appliances and is less flexible than process-focused facility.
3. **Product Focus;** It is a facility organised around products, a product oriented, high-volume low variety process.
   - It is also referred to as **continuous process** because it has very long continuous production run.
   - Examples of product focussed processes are steel, glass, paper, electric bulbs, chemicals and pharmaceutical products, bolts and nuts etc.

Process Analysis and Design;(June 2015) Process Analysis and Design is a systematic approach to improve our understanding of the business processes of an organization to assist in the realization of tangible benefits such as cost reduction, process efficiency, and effective human resource allocation.



Process Analysis and Design

Process Management; Process management is concerned with the selection of inputs, operations, work flows and methods that transform inputs into outputs. The starting point of input selection is the make-or-buy decision (i.e.,

deciding which parts and components are to be produced in-house and which are to be purchased from outside suppliers).

Companies begin the process of organizing operations by setting competitive priorities. That is they must determine which of the following eight priorities are to be emphasized as competitive advantages:

1. Low-cost operations	2. High performance design
3. Consistent quality	4. Fast delivery time
5. On-time delivery	6. Development speed
7. Product customization	8. Volume flexibility

Process Decisions; It must be made when:

a. a new or modified product or service is being offered
b. quality must be improved
c. competitive priorities have changed
d. demand for a product or service is changing
e. cost or availability of materials has changed
f. Competitors are doing better by using a new technology or a new process.

Major Process Decisions;

1. Process Choice; The production manager has to choose from five basic process types
   a. Job Shop Process;

   b. Batch Process

   c. Repetitive Process; This is used when higher volumes of more standardised goods or services are needed.
      - This type of process is characterised by slight flexibility of equipment (as products are standardised) and generally low labour skills
      - Products produced include automobiles, home appliances, television sets, computers, toys etc.
      - Repetitive process is also referred to as **line process** as it include **production lines** and **assembly lines** in mass production
   d. Continuous Process; This is used when a very highly standardised product is desired in high volumes.
      - These systems have almost no variety in output and hence there is no need for equipment flexibility.
      - A continuous process is the extreme end of high volume, standardized production with rigid line flows
      - The process often is capital intensive and operate round the clock to maximise equipment utilisation and to avoid expensive shut downs and shut ups.
      - Examples of products made in continuous process systems include petroleum products, steel, sugar, flour, paper, cement, fertilisers etc.
   e. Project Process; It is characterised by high degree of job customisation, the large scope for each project and need for substantial resources to complete the project.
      - Examples of projects are building a shopping centre, a dam, a bridge, construction of a factory, hospital, developing a new product, publishing a new book etc.
2. Vertical Integration; (Dec 2013) **Vertical integration** is the degree to which a firm's own production system handles the entire supply chain starting from procurement of raw materials to distribution of finished goods.

➢ When managers decide to have more vertical integration, there is less outsourcing
➢ The vertical integration is based on **"make-or-buy" decisions**, with **make** decisions meaning more integration and a **buy** decision meaning less integration and more outsourcing.

Two directions of vertical integration are; (Dec 2014)

a. Backward integration which represents moving upstream toward the sources of raw materials and parts
b. Forward integration in which the firm acquires the channel of distribution (such as having its own warehouses, and retail outlets).(Dec 2013) (Dec 2014)

Advantages of vertical integration are:

(i) Can sometimes increase market share and allow the firm enter foreign markets more easily.
(ii) Can achieve savings in production cost and produce higher quality goods.
(iii) Can achieve more timely delivery.
(iv) Better utilisation of all types of resources.

Disadvantages of vertical integration are:

(i) Not attractive for low volumes.
(ii) High capital investment and operating costs.
(iii) Less ability to react more quickly to changes in customer demands, competitive actions and new techniques.

3. Resource Flexibility; **Resource flexibility** is the ease with which equipments and workers can handle a wide variety of products, levels of output, duties and functions.
4. Customer Involvement; **Customer involvement** refers to the ways in which customers become part of the production process and the extent of their participation.
5. Capacity Intensity; **Capital intensity** is the mix of equipment and human skills in a production process.
   - ✓ Capital intensity will be high if the relative cost of equipment is high when compared to the cost of human labour.
   - ✓ **Capital intensity** means the predominant resource used in manufacturing, i.e., capital equipments and machines rather than labour.
   - ✓ Decision regarding the amount of capital investment needed for equipments and machines is important for the design of a new process or the redesign of an existing one.

Production Planning

Production planning and control may be defined as the planning, direction and coordination of the firm's material and physical facilities towards the attainment of predetermined production objectives in the most economical manner.

Scope of Production Planning and Control (PPC) Functions; (Dec 2014) (9 Mark)

1. Materials; Raw materials, spare parts and components which must be available in the correct quantities and specifications at the right time.
2. Methods; It involves deciding the best sequence of operations for manufacturing the parts, building up subassemblies and major assemblies which in turn will make up the finished product, within the limitations of existing layout and workflow.
3. Machines and Equipments; PPC is concerned with selection of machines and equipments and also with maintenance policy, procedure and schedules, replacement policy and tooling. (Design and manufacture of tools).
4. Routing; Routing prescribes the flow of work in the plant and is related to consideration of layout, of temporary storage locations for raw materials, components and semi processed parts, and of material handling systems. Routing is a basic PPC function.
5. Estimating The processing times (both set up time and operation time per piece) required for the parts to be manufactured in-house are estimated and the standard time (both machine time and labour time) are established as performance standards.;
6. Loading and Scheduling; Machines have to be loaded according to their capacity and capability. Machine loading is carried out in conjunction with routing (as indicated in process layouts or operations analysis and routing sheets) to ensure smooth workflow and the prescribed feeds. Speeds of machines are adhered to as well as the estimated time (standard time which is the allowed time to do a job.
   Scheduling: Determines the utilisation of equipment and manpower and hence the efficiency of the plant.
7. Dispatching; This is concerned with the execution of planning functions.
8. Expediting or Progressing: This means follow-up or keeping track of the progress made in completing the production as per schedules. This follows dispatching function logically.
9. Inspection
10. Evaluating and Controlling;

Principles of Production Planning and Control (PPC)

1. Type of production determines the kind of production planning and control system needed.
2. Number of parts involved in the product affects expenses of operating PPC department.
3. Complexity of PPC function varies with the number of assemblies involved.
4. Time is a common denominator for all scheduling activities.
5. Size of the plant has relatively little to do with the type of the PPC system needed.
6. PPC permits 'management by exception'.
7. Cost control should be a by-product of PPC function.

Prime Objectives of Production Planning and Control

- Profits of the enterprise; This is accomplished by keeping the customers satisfied through the meeting of delivery schedules.

Prime Advantages;

- Efficiency and economy are maximized; The 4 Ms -resources of men, machinery, materials and money are analysed to select the most appropriate materials, methods, and facilities for accomplishing the work. This is followed by functions such as routing, estimating and scheduling.

General Objectives of Production Planning Control;

a. To deliver quality goods in required quantities to the customer in the required delivery schedule to achieve maximum customer satisfaction and minimum possible cost.
b. To ensure maximum utilization of all resources.
c. To ensure production of quality products.
d. To minimise the product through-put time or production/manufacturing cycle time.
e. To maintain optimum inventory levels.
f. To maintain flexibility in manufacturing operations.

g. To plan for plant capacities for future requirements.
h. To remove bottle-necks at all stages of production and to solve problems related to production.
i. To ensure effective cost reduction and cost control.
j. To produce effective results for least total cost.

Production Control;

Importance of Control Function; The function of production control is to;

i. Provide for the production of parts, assemblies and products of required quality and quantity at the required time.
ii. Co-ordinate, monitor and feedback to manufacturing management, the results of the production activities, analyzing and interpreting their significance and taking corrective action if necessary.
iii. Provide for optimum utilisation of all resources.
iv. Achieve the broad objectives of low cost production and reliable customer service..

Benefits of Production Control;

1. Improvement in profits through;
   a. Maintenance of a balanced inventory of materials, parts, work-in-process and finished goods.
   b. Balanced and stabilized production.
   c. Maximum utilization of equipment, tooling, labour (manpower) and storage space.
   d. Minimum investment in inventory.
   e. Reduction in indirect costs.
   f. Reduction in set up costs.
   g. Reduction in scrap and rework costs.
2. Competitive advantage-
   a. Reliable delivery to customers.
   b. Shortened delivery schedules to customers.
   c. Lower production costs and greater pricing flexibility.
   d. Orderly planning and marketing of new or improved products.

Elements of Production Control;

a. Control of Planning; Assure receipt of latest forecast data from sales and production planning, bill of material data from product engineering and routing information from process engineering.
b. Control of Materials; Control of inventory and providing for issue of materials to the shop and movement of materials within the shop.
c. Control of Tooling; Check on the availability of tooling and provide for issue of tools to shop floors from tool cribs.
d. Control of Manufacturing Capacity;
e. Control of Activities; Release order and information at assigned times.;
f. Control of Quality; Control of Due Dates
g. Control of Material Handling; Control of Information

Phases in Production Planning and Control Function; (Dec 2014 Set 2)

1. Planning Phase;
   a. Pre-planning; Pre-planning activity involves product planning and development, demand forecasting, resources planning, facilities planning, plant planning, plant location and plant layout.
   b. Active Planning; Active planning involves planning for quantity, determination of product - mix, routing, scheduling, material planning, process planning, capacity planning and tool planning.
2. Action Phase; Execution or implementation phase includes dispatching and progressing function.
3. Control Phase; Includes status reporting, material control, tool control, inventory control, quality control, labour output control and cost control.

Production Planning Functions; The main functions of production planning are; (Dec 2014)

1. Estimating; Involves deciding the quantity of products to be produced and cost involved in it on the basis of sales forecast.
   - ✓ Estimating manpower, machine capacity and materials required (Bill of material is the basis) to meet the planned production targets are the key activities before budgeting for resources.
2. Routing; This is the process of determining the sequence of operations to be performed in the production process.

- ✓ Routing determines what work must be done, where and how?
- ✓ Routing information is provided by product or process engineering function and it is useful to prepare machine loading charts and schedules.

A route sheet is a document providing information and instructions for converting the raw materials into finished parts or products.

- ✓ It defines each step of the production operation and lays down the precise path or route through which the product will flow during the conversion process.

3. Scheduling; (Dec 2014)Involves fixing priorities for each job and determining the starting time and finishing time for each operation, the starting dates and finishing dates for each part, sub assembly and final assembly.
   - ✓ Scheduling lays down a time table for production indicating the total time required for the manufacture of a product and also the time required for carrying out the operation for each part on each machine or equipment.
4. Loading; Facility loading means loading of facility or work centre and deciding which jobs to be assigned to which work centre or machine. Loading is the process of converting operation schedules into practice.
   - ✓ Machine loading is the process of assigning specific jobs to machines, men or work centers based on relative priorities and capacity utilization.
   - ✓ A machine loading chart (Gantt chart) is prepared showing the planned utilisation of men and machines by allocating the jobs to machines or workers as per priority sequencing established at the time of scheduling,

   Loading ensures maximum possible utilisation of productive facilities and avoids bottlenecks in production.

Production Control Functions; The Control functions are;

1. Dispatching; Dispatching may be defined as setting production activities in motion through the release of orders (work order, shop order) and instructions in accordance with the previously planned time schedules and routings.
2. Expediting/Follow up/Progressing; Expediting or progressing ensures that the work is carried out as per plan and delivery schedules are met.

Basic Types of Production Control;

1. Block Control; Textiles and books and magazine printing
2. Flow Control; chemicals, petroleum, glass
3. Load Control; bottleneck machine exist in process of manufacturing (Dec 2013)
4. Order control; employed in companies with intermittent production systems;
5. Special project control; bridges, schools, hospitals etc.
6. Batch control; food processing industries;

Production Planning and Control in Different Production Systems;

1. PPC in Job Production;
2. PPC in Batch Production
3. PPC in Continuous Production;
   a. Mass Production
   b. Row Production.
4. PPC in Process Industry;

Requirement of Effective Production Planning and Control System;

1. Sound organizational structure with mechanism for proper delegation of authority and fixation of responsibility at all levels.
2. Information feedback system should provide reliable and up-to-date information to all persons carrying out PPC functions.
3. Standardisation of materials, tools, equipments, labour, quality, workmanship etc.
4. Trained personnel for using the special tools, equipments and manufacturing processes.
5. Flexibility to accommodate changes and bottle-necks such as shortage of materials, power failures, machine break downs and absenteeism of employees.
6. Appropriate management policies regarding production and inventory levels, product -mix and inventory turnover.
7. Accurate assessment of manufacturing lead times and procurement lead times.
8. Plant capacity should be adequate to meet the demand. The plant should be flexible in order to respond to the introduction of new products, changes in product-mix and production rate.

Limitations of PPC;

(a) Production planning and control function is based on certain assumptions or forecasts of customers' demand, plant capacity, availability of materials, power etc. If these assumptions go wrong, PPC becomes ineffective.

(b) Employees may resist changes is production levels set as per production plans if such plans are rigid.

(c) The production planning process is time consuming when it is necessary to carry out routing and scheduling functions for large and complex products consisting of a large no. of parts going into the product.

(d) Production planning and control function becomes extremely difficult when the environmental factors change very rapidly such as technology, customers' taste regarding fashion or style of products needed, Government policy and controls stoppages of power supply by electricity boards due to power cuts, break in supply chain due to natural calamities such as floods, earthquakes, war etc.

Capacity Planning;

Capacity of a facility is referred to as its capability to produce. Capacity should be able to meet the present and future Demand and to some extent the sudden demands too.

Definition; Capacity is the rate of output from an operating system per unit time. Capacity is based on the output that the system can produce, store, and transport. For example, a cement plant could be capable to produce 3000 tons per day (tpd) of cement. Capacity planning decision involves the following considerations:

a. What is the present capacity?
b. What is the expected future capacity needs in the projected planning period?
c. What are the options to meet the demand and how the capacity could be modified to meet the need?
d. Evaluation of various options of capacity from financial, economical and technological considerations.
e. Selection of the most appropriate option for the capacity to achieve the objectives.

Classification of Capacity; Capacity is classified in many ways such as budgeted, dedicated, productive, protective, rated, safety, standing, and demonstrated. Mainly, the classification of capacity is talked in terms of:

1. Designed or rated capacity; Designed capacity is also the maximum capacity, which a facility can achieve. Designed capacity is usually higher than the normal output rate.
   The designed capacity of a process is calculated by taking into account the following:
   - ✓ Number of machines available
   - ✓ Capacity of each machine
   - ✓ Number of shifts operated
   - ✓ Duration of each shift
   - ✓ Number of workdays in the period under consideration.

   Capacity of the process is expressed in terms of above factors as shown below:

   Capacity of the process = $CN_1N_2N_3H$

   Where C = Capacity of machine per hour

   N_1 = Number of machines

   N_2 = Number of shifts per day

   N_3 = Number of days in the time period

   H = Hours in each shift

   Assumptions;
   1. The workers performing the job are working with the same efficiency.
   2. There is no loss of time during product changeover.
   3. The process does not face machine breakdown or low rate of production during machine operation.
   4. Preventive or planned shutdowns are not included in the process time.
   5. No overtime is included.
   6. Workers are working at a normal rate.
   7. No loss of time due to worker problems.

<u>The maximum capacity is increased by the following actions:</u>

   a. Increase the number of machines
   b. Increase the number of operating hours in the shift
   c. Increase the number of shifts, if possible
   d. Deploy trained manpower
   e. Avoid loss due to scrap or damages
   f. Control waste of time by workers
   g. Give incentives to workers to perform at a higher rate

2. Planned Capacity; Planned capacity is the capacity, which is maintained or achieved in normal operations.
   Planned capacity is <u>usually less than the designed capacity due to the following reasons:</u>
   1. Unexpected demand disturbs the planned programme.
   2. Variation in the time taken in completing the preventive and predictive maintenance.

3. Repairs time
4. Strain for both men and machine to run at maximum capacity.

A. The efficiency measures the ratio of planned resource allocation for a process and the actual resource consumed by the process.

Efficiency = Standard time/Actual time

B. Utilization is the percentage of a resource's maximum capacity, which is expected to involve in production.

Utilization = Actual hours/Scheduled available hours

- ✓ Utilization factor and efficiency are both assumed to develop realistic and feasible plans.
- ✓ Unlike the utilization factor, efficiency, can exceed 100 percent, if the rate of work is higher than the standard performance.

Planned capacity is therefore calculated by determining the designed capacity and multiplying the same with the utilization factor and efficiency.

Planned capacity = Designed capacity × Efficiency × Utilization factor.

3. Demonstrated Capacity; The actual level of output for a process over a period of time is known as the demonstrated capacity. Demonstrated capacity is determined by averaging the recorded figures of actual output over a period of time. It might differ from both the designed and the planned capacities for various reasons, such as;
   - Product mix
   - Operator skill and experience
   - Health of equipment or machines
   - Type of jobs
   - Quality of materials
   - Inaccurate standards for process performance
   - Idle time
   - Blockages
   - Rejection due to poor quality

   Units of Measure for Capacity; Capacity is expressed by a particular unit. The choice for a particular unit differs based on the business or on the product.

Capacity Measurement Over Time Spans; Capacity available and capacity required are measured in the following time spans:

a. Short-term Capacity Requirement Plans.
b. Intermediate term Rough Cut Capacity Plans.
c. Long-term Resource Requirement Plans.

Capacity Management; Capacity management is concerned with the matching of the capacity of the operating system and the demand placed on that system..The existing capacity could be optimally utilized by identifying and eliminating the problems. It is essential to diagnose the problem and correct the situation, which might not even need any additional investment. Energy audit and technical audit studies etc.

Management encounters three situations as follows:

1. Designed capacity > Planned capacity > Demonstrated capacity; In this situation, demonstrated capacity falls short of planned capacity and occurs due to problems with inputs or with the available level of capacity.
   Reasons;
   - Too many setups needed for large number of products.
   - Inadequate skill and experience or operators.
   - Excessive breakdowns of machine.
   - Blockages.

- Rejections and rework.

2. Designed capacity > Demonstrated capacity > Planned capacity; Demonstrated capacity is more than the planned capacity due to the following:
   - Optimum product mix does not require setups.
   - Deployment of well trained and experienced staff on the job help in high capacity outputs.
   - Quality of incoming material is monitored.
   - Less rejection rate, scrap and rework.
3. Designed capacity = Demonstrated capacity > Planned capacity; In this situation, the system produces more than the production plans demand using all its available capacity. If the situation continues for long, it shows the threat of insufficient capacity and could be responded to in the following manner:
   a. Add capacity:
   b. Change the Process:
   c. Reduce the input rate at which the orders enter the process.

Capacity Management Strategies for dealing with Demand Fluctuations; Faced with fluctuating and uncertain demand levels there are two basic capacity planning strategies which might be employed:

1. Providing for efficient adjustment or variation of - system capacity; and
2. Eliminating or reducing the need for adjustments in system capacity.

Capacity Planning Procedures;

1. Aggregation; Capacity planning will seek to estimate or measure all demands and express the total in such a way as to enable enough of all resources (or total capacity) to be provided. The implication is that such planning is concerned with total demand, i.e. all demands collected together.
2. Economic Operating Levels; shows the relationship between the unit cost of processing and the throughput rate for a hypothetical situation.
3. Cumulative graphs; This is a procedure for comparing alternative capacity plans for a period, particularly where there is a need to balance the costs of changing capacity against cost of insufficient or extra capacity. The capacity provided to satisfy estimated demand will be influenced by the strategy employed for meeting demand fluctuations.
4. Linear Programming; This approach provides a means of allocating available capacity and inventories against a forward demand in such a way as to balance these costs and smooth the level of operations. (Will be discuss later in detail).
5. Heuristic Methods; Due to the computational complexity of most of the practical relevant optimization problems, heuristic methods form an important class of solution methods for such problems. A heuristic is a method that *'on* the basis of experience or judgement seems likely to yield a good solution to the problem, but cannot be guaranteed to produce an optimum'
6. Queuing Theory Methods; (Will be discuss later in detail). In queuing theory a model is constructed so that queue lengths and waiting time can be predicted. The methods used to describe and analyse queuing situations depend on the form of the system, in particular:
   a. number of servicing units;
   b. configuration of servicing units, i.e. whether in parallel or in series;
   c. queue discipline;
   d. distribution of arrival times;
   e. distribution of service times.

A Systematic Approach to Capacity Decision; A four-step procedure generally can help managers make sound capacity decisions.

1. Estimate future capacity requirements.
2. Identify gaps by comparing requirements with available capacity.
3. Develop alternative plans for filing the gaps.
4. Evaluate each alternative, both qualitative and quantitative, and make a final choice.

Process Planning

Procedure for process planning and design

1. The inputs required comprise the product design information, production system information and product strategy decisions.
2. Process planning and design starts with selection of the types of processes, determining the sequence of operation, selection of equipment, tooling, deciding about the type of layout of facilities and establishing the control system for efficient analysing of resources to achieve most economical production of the product.
3. The outputs are specific process plans, route sheets, flow charts, assembly charts, installation of equipments, machinery, material handling systems and providing trained, skilled employees to carryout the production processes to achieve the desired results.

Purpose of Process Charts

- Process charts can present a picture of a given process so clearly that every step of the process can be understood by those who study the charts.
- Process charts may be effective in process analysis and may help in detecting inefficiencies of the processes currently adopted.

Types of Process Charts; Process charts can be classified as operation process charts, flow process charts, worker-machine/ man-machine charts and activity charts or multiple activity charts.

Process Improvement; It is a systematic study of the activities and flows of each process to improve the process. Once the process is thoroughly understood, it can be improved.

Process improvement is necessary when:

a. the process is slow in responding to the customer,
b. the process introduces too many quality problems or errors,
c. the process is costly,
d. the process is a bottleneck, with work accumulating and waiting to go through it, and
e. the process involves waste, pollution and little value addition.

Plant Layout; A plant layout refers to the arrangement of machinery, equipment and other industrial facilities – such as receiving and shipping departments, tools rooms, maintenance rooms, employee amenities, etc., - for the purpose of achieving the quickest and smoothest production at the least cost.

Factors Influencing Layout;

1. **Materials:** storage and movement of raw materials in a plant until they are converted into finished products
2. **Product:** A layout is designed with the ultimate purpose of producing a product.
3. type, position and requirements of employees
4. The type of product, the volume of its production, the type of process and management policy
5. **Type of industry:**
6. **Location**
7. **Managerial Policies:**

Principles of Layout;

1. The Principle of Minimum Travel:
2. Principle of Sequence:
3. Principle of Usage:
4. Principle of Compactness:
5. Principle of Safety and Satisfaction:
6. Principle of Flexibility:
7. Principle of Minimum Investment:

TYPES OF LAYOUT;

a. Process layout; Also called the functional layout, layout for job lot manufacture on batch production layout, the process layout involves grouping together of like machines in one department

b. Product layout; Also called the straight-line layout or layout for serialized manufacture (the term straight-line, as applied to production, refers to the movements which do not involve backtracking or crossing of the line of movement of the product), the product layout involves the arrangement of machines in one line , depending upon the sequence of operations.

Product Layout	Process Layout
1. Mechanisation of materials handling and consequent reduction in materials handling cost.	1. Reduction in the investment on machines as they are general purpose machines.
2. Avoidance of bottlenecks.	2. Greater flexibility in production.
3. Economy in manufacturing time.	3. Better and more efficient supervision possible through specialization.
4. Better production control.	4. Better scope for expansion.
5. Less floor area required per unit of production.	5. Better utilization of men and machines.
6. Minimum investment in work-in-progress	6. Easier to handle breakdowns of equipment by transferring work to another machine or station.
7. Early detection of mistakes or badly produced items.	7. Full utilization of the plant.
8. Greater incentive to a group of workers to raise their performance.	8. Greater incentive to individual workers to raise the level of their performance.

c. Fixed position layout; The fixed position layout involves the movement of men and machines to the product which remains stationary. In this type of layout, the material or major component remains in a fixed location, and tools, machinery and men as well as other pieces of material are brought to this location.

d. Cellular Manufacturing (CM) layout; In cellular manufacturing (CM), machines are grouped into cells, and the cells function somewhat like a product layout within a larger shop or process layout. A distinct feature of CM is that the number of cells is relatively small and the number of production machines per cell is also small

e. A combination of the above.

LAYOUT PLANNING; The process of preparing a layout is an art as well as a science, in spite of the advances made in the use of layouts. The layout procedure might start with an analysis of the product to be manufactured and the expected volume of its production. An analysis of the product includes a study of the parts to be manufactured and/or bought, and the stages at which they should be assembled to obtain the end product.

Layout Tools and Techniques;

1. **Templates :** A plant layout template is a scaled representation of a physical object in a layout. This object may be a machine, materials handling equipment, a worker or even materials. The templates are fixed to plan drawing and are moved around the drawing to explore the various layout possibilities until a layout, which eliminates unnecessary handling and back-tracking of materials and offers flexibility to admit revisions at the least cost, emerge
2. **Operations Sequence Analysis;** Being an early approach to process layouts, operations sequence analysis develops a good scheme for arrangement of departments graphically analysing the layout problem.
3. **Line Balancing :** Line balancing is the phase of assembly line study that nearly equally divides the work to be done among the workers so that the total number of employees required on the assembly line is minimised. Line balancing is not simple; in fact, there are usually many alternative ways that the work can be divided among the workers. Operation researchers have used linear programming dynamic programming and other optimal methods to study line balancing problems.

Criteria for Selection and Design of Layouts;

a. Material handling cost and
b. Worker effectiveness

The various methods used for selecting the best layout among several alternatives layouts are

a. **Travel Chart Method;** The trave chart which is also known as from-to-chart is helpful in analysing the overall flow of material. It shows the number of moves made between departments and identifies the most active departments.

b. **Load-Distance Analysis Method;** This method helps to minimise transportation costs by evaluating alternate layouts on the basis of the total of the product of actual distance moved and the load (the units moved) for each layout alternative.

c. **Systematic Layout Planning;** Systematic layout planning (SLP) method is used in some production systems such as service systems, where the amount of material that flows between departments may not be critical for developing a good facility layout. This method develops a chart known as "relationship chart" or Richard Muther's halfmatrix, which rates the relative importance of locating one department close to another department.

Layout Design Procedure;

1. Statement of specific objectives, scope and factors to be considered.
2. Collection of basic data on sales forecasts, production volumes, production schedules, part lists, operations to be performed and their sequences, work measurement, existing layouts, building drawings.
3. Preparation of various kinds of charts such as flow process charts, flow diagram, string diagram, templates etc.
4. Designing the production process.
5. Planning the material flow pattern and developing the overall materials handling plan.
6. Calculation of requirement of work centres and equipments.
7. Planning individual work centres.
8. Selection of materials handling equipments.
9. Determining storage requirements.
10. Planning of auxiliary and service facilities.

Plant Location; Plant location may be understood as the function of determining where the plant should be located for maximum operating economy and effectiveness

STEPS IN LOCATION;

a. Deciding on Domestic or International Location
b. Selection of Region; The following factors influence such selection:
   - ✓ Availability of Raw Materials
   - ✓ Nearness to the Market:
   - ✓ Availability of Power:
   - ✓ Transport Facilities:
   - ✓ Suitability of Climate:
   - ✓ Government Policy:

c. Selection of a Community; Selecting a particular locality or community in a region is the third step in plant location.

   - ✓ Availability of Labour:
   - ✓ Civic Amenities for Workers:
   - ✓ Existence of Complementary and Competing Industries :
   - ✓ Finance and Research Facilities:
   - ✓ Availability of Water and Fire-Fighting Facilities
   - ✓ Local Taxes and Restrictions:
   - ✓ Momentum of an Early Start:
   - ✓ Personal Factors :

d. Selection of the Site

   - ✓ **Soil, Size and Topography:**
   - ✓ **Disposal of Waste :**

Project Management;

Project is an organisational unit dedicated to the allotment of a goal, the successful completion of a development product in time, within specified budget, in conformance with the pre-determined performance specifications. It is a set of finite activities that are usually prepared only once and have well designed objectives, using a combination of human and non-human resources within limits of time. It consists of a series of non-routine, interrelated activities.

Project Characteristics;

1. Projects have a purpose:
2. Source:
3. Focus
4. Lifespan:
5. Unique:
6. Unity in Diversity:
7. Flexibility
8. Team Spirit:
9. Risk and Uncertainty:
10. Statement of Work (SOW): Project planning deals with specified tasks, operations or activities, which must be performed to achieve project goals. A project starts with statement of work.
11. Implementation:
12. Task:
13. Work Package:
14. Subcontracting:
15. Project Life Cycle:
16. Feasibility Study**:** Feasibility study of the project is the most exhaustive of all the planning stage. The project is systematically examined in depth at this stage for various aspects like technical, financial, economical, commercial, social, managerial and organisational. The purpose of this study is to examine if the project objectives are realistic, recommendation in preliminary study are technically sound; beneficial from financial, economical, social point of view; feasibility from social, cultural, ecological view.

Phases in Project Life Cycle

The five main phases are as follows:

1. Conception phase
2. Definition phase
3. Planning and organising phase
4. Implementation phase
5. Project clean-up phase

Techniques for Project Management;

1. **Project Selection Technique**
   - Cost benefit analysis
   - Risk and sensitivity analysis
2. **Project Execution Planning Techniques**
   - Work breakdown structure (WBS),
   - Project execution plan (PEP),
   - Project responsibility matrix, and
   - Project management manual.
3. **Project Scheduling and Co-ordinating Techniques**
   - Bar chart,
   - Project life cycle ,
   - Line of balance (LOB), and
   - Networking techniques (PERT/CPM).
4. **Project Monitoring and Progressing Techniques**
   - Progress measurement technique,

- Performance monitoring technique, and
- Updating, reviewing and reporting technique.

5. **Project Cost and Productivity Control Techniques**
   - Productivity budgeting technique,
   - Value engineering, and
   - Cost calculation using WBS.
6. **Project Communications and Clean-up Techniques**
   - Control Room, and
   - Computerised information systems.

Roles and Attributes for Project Manager;

1. Projectising and problem solving.
2. Defining and maintaining integrity of a project.
3. Development of Project Execution Plan.
4. Setting of cost and time targets for each of the projects,
5. Development of systems and procedures for accomplishment of project objectives and targets.
6. Negotiation for commitments and Man-management.
7. Non-human resource management, including fiscal matters.

Attributes of a good Project Manager are:

1. Planning and organisational skills.
2. Conflict resolving capacity.
3. Ambition for achievement.
4. Personnel management skills.
5. Communication skills.
6. Ability to solve problems in their totality.
7. High energy levels.
8. Ability to take suggestions.
9. Ability to develop alternative course of actions quickly.
10. Knowledge of project management methods, tools and technology.

Project Planning; The process of project planning involves the following steps:

1. Defining the objectives and goals of the project.
2. Making forecasts for achieving the goals.
3. Identifying the various course of actions through available alternatives and assumptions.
4. Evaluating the available resources.
5. Evaluating and selecting the available course of action for achieving the desired objective under the resource constraints.

Resource Planning; The resource-planning component includes the ability to plan and manage resources required to deliver a project. This starts with selection of an agency and assignment of the project team and includes the management of the resources assigned to that team.

Factors Influencing the Scheduling of Projects

1. Changes
2. Uncertainties
3. Database

Gantt Chart; Gantt chart is one of the oldest techniques used for planning, scheduling and controlling of projects. Gantt chart was developed by H.L. Gantt in 1917 and is in use till today. Gantt charts were used even before computer came on the scene.

Gantt chart is a graphical representation of a series of activities drawn to a. time scale. Horizontal axis (X-axis) represents time and vertical axis (Y-axis) shows the activities to be performed. The Gantt chart shows activities to specific jobs at individual/work centers by horizontal bars. Also known as a 'bar chart' because of its graphic presentation of the information, the position and the length of the horizontal bar indicate the start and completion date of the activity.

Human Resource Planning; "Human Resource Planning (HRP) is the process – including forecasting, developing, implementing, and controlling – by which a firm ensures that it has the right number of people and right kind of people doing things for which they are economically most suitable'.

Importance of Human Resource Planning;

1. **Defining future personnel need:**
2. **Coping with Changes:**
3. **Providing Base for Developing Talents:**
4. **Increasing Investment in Human Resources:**
5. **Forcing Top Management to involve in HRM.**

Human Resource Planning Process

1. Forecasting future manpower requirements,
2. Inventorying present manpower resources
3. Anticipating manpower problems by projecting present resources
4. Planning the necessary programmes of recruitment, selection, training, deployment, utilisation, transfer, promotion, development, motivation and compensation.

Techniques for forecasting Human Resource needs;

1. Managerial judgement method; In this method managers prepare the forecast of human resource needs of various categories for their own departments based on their past experiences
2. Delphi technique
3. Work-study technique
4. Ratio-trend analysis; Under this method, the main emphasis is on the ratios between production/sales level and direct operatives; ratios between direct operatives; and other personnel, say supervisory and managerial personnel.
5. Statistical and mathematical model

Studies at Work Place;

Work Study; Work study is a technique which is employed to ensure the best possible use of men, machine, materials and energy in carrying out a specific activity. It deals with the techniques of method study and work measurement.

Work study is based on the principle that for every job, there is:

a. One best way of doing it.
b. A scientific method is the best and surest way of finding this best way.
c. The time taken for doing the job by the best way can be measured and set as standards. (Time Study)

Benefits of Work Study;

1. Increased productivity and operational efficiency.
2. Reduced manufacturing costs.
3. Improved work place layout.
4. Better manpower planning and capacity planning.
5. Fair wages to employees.
6. Better working conditions to employees.
7. Improved work flow.
8. Reduced material handling costs.
9. Provides a standard of performance to measure labour efficiency.
10. Basis for sound incentive scheme.

Other Terms;

1. Work Measurement The application of techniques designed to establish the time for a qualified worker to carry out a specified job at a defined level of performance..
2. Method Study or Methods Analysis or Operations Analysis; The systematic recording and critical examination of existing and proposed ways of doing work as a means of developing and applying easier and more effective methods and reducing costs.
3. Work Simplification; Involves improvements in work methods or work flow initiated and developed by workers or supervisors on the job as a result of methods training and/or economic incentives.
4. Industrial Engineering; Concerned with the design, improvement and installation of integrated systems of men, materials and equipments to improve productivity.

Method Study or Methods Analysis; Work methods analysis or method study is a scientific technique of observing, recording and critically examining the present method of performing a task or job or operation with the aim of improving the present method and developing a new and cheaper method.

Objectives of Method Study;

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

Advantages of Method Study;

1. Work simplification
2. Improved working method (cheaper method)
3. Better product quality
4. Improved workplace layout
5. Improved equipment design
6. Better working conditions/environment
7. Better material handling and lesser material handling cost
8. Improved work flow
9. Less fatigue to operator
10. Shorter production cycle time
11. Reduced material consumption and wastages
12. Reduced manufacturing cost and higher productivity

Factors Facilitating Method Study;

1. High operating cost
2. High wastage and scrap
3. Excessive movement of materials and workmen
4. Excessive production bottlenecks
5. Excessive rejections and rework
6. Complaints about quality
7. Complaints about poor working condition
8. Increasing number of accidents
9. Excessive use of overtime

Method Study Procedure;

1. Select the work or job to be studied and define the objectives to be achieved by method study.
2. Record all the relevant facts or information's pertaining to the existing method using the recording techniques
3. Examine the recorded facts critically challenging everything being clone and seeking alternatives, questioning the purpose (What is achieved?), the means (How is it achieved?), sequence (When it is achieved?), place (Where it is achieved?), and the person (Who achieves it?).
4. Develop the improved method by generating several alternatives and selecting the best method.
5. Install the improved (new) method in three phases, planning, arranging and implementing phases.
6. Maintain the new method by ensuring that the installed method is functioning well.

Recording Techniques Used in Method Study;

Recording Technique	Information Recorded
(a) Charts	
1. Outline process chart	Principle operations and inspection of the processes.
2. Flow process chart	Activities of men, material or equipment are analyzed into five events viz., operation, transport, inspection, delay and storage.
3. Two-handed process chart	Movements of two hands or limbs of the operator.
4. Multiple activity chart	Simultaneous/interrelated activities of operators and/or machines on a common time scale.
5. Simultaneous Motion Cycle Chart (SIMO)	Movement of body members of the operator, expressed in terms of therbligs on a common time scale.
(b) Diagrams and Models	
1. Flow diagram	Path of men, materials and equipments on a scale model.
2. String diagram	Same as above except for the variation that it uses string to trace the path.
(c) Photographic aids	
1. Cyclegraph	Movement of hand obtained by exposing a photographic plate to the light emitted from small bulbs attached to the operator's fingers.
2. Chrono-cyclegraphs	Modification of cyclegraph in which recording is made using flash light.

(June 2015)

Symbols used in Process Chart

Symbol	Activity	Purpose for which it is used
○	Operation	Indicates the main steps in a process, method of procedure, usually the part, material or product concerned which is modified or changed during the operation.
→	Transport	Indicates movement of workers, material or equipment from place to place.
□	Inspection	Indicates any type of inspection, check, measurement, visual scrutiny for quality and/or quantity.
D	Temporary storage or delay	Indicates a delay in the sequence of events.
▽	Storage	Indicates a controlled storage in which material is received into or issued from stores under some form of authorization or an item is retained for reference purposes.

Motion Study; It is defined as a systematic and critical study of existing method of doing a task with a view to evolve the most efficient and economic method of doing it.

It is a method for setting up employee productivity standards in which:

- A complex job is broken down into small or simple steps.
- The sequence of movements taken by the employee in performing those steps is carefully observed to detect and eliminate wasteful motion.
- Precise time taken for each correct movement is measured.

Motion Economy; **Motion economy** helps achieve productivity and reduce Cumulative Trauma at the workstation or sub-micro level. The Principles of **Motion Economy** eliminate wasted**motion**, ease operator tasks, reduce fatigue and minimize cumulative trauma such as Carpal Tunnel and tendonitis.

Principles of Motion Economy; The rules of motion economy and efficiency which referred to hand motions of operators were developed by Gilbreths. The principles of motion economy are divided into three groups, viz.,

a. Effective use of the operator
b. Arrangement of the workplace
c. Tools and equipment.

Work Measurement; Work measurement is defined as the application of techniques designed to establish the work content of a specified task by determining the time required for carrying out the task at a defined standard of performance by a qualified worker.

Benefits of Work Measurement; Work measurement helps;

1. To develop a basis for comparing alternate methods developed in method study by establishing the work content in each method of doing the job.
2. To prepare realistic work schedules by accurate assessment of human work.
3. To assist in labour cost estimation.
4. To provide information related to estimation of tenders, fixation of selling price and assessment of delivery schedule.
5. To compare actual time taken by the worker with the allowed time (standard time) for proper control of labour.

Techniques of Work Measurement; The main techniques used to measure work are:

1. Direct Time Study.
2. Synthesis Method.
3. Analytical Estimating.
4. Pre determined Motion Time System (PMTS).
5. Work Sampling or Activity Sampling or Ratio Delay Method.

Important Work measurement techniques are as follows;

1. Time Study; Time study is concerned with the determination of the amount of time required to perform a unit of work.
   It consists of the process of observing and recording the time required to perform each element of an operation so as to determine the reasonable time in which the work should be completed.

Time Study; Steps;

1. **Select the Job to be Studied**
2. **Select the Worker to be Studied**
3. **Conducting Stop Watch Time Study**
   a. Obtain and record all information available about the job, operator and working conditions
   b. Record the method of doing the job and break down the job into elements. An **element** is a distinct part of a specified job selected for convenience of observation, measurement and analysis.
   c. Examine the various elements to ensure that the most effective motions are used in the elements of job performed.
   d. Measure the actual time taken by the operator to perform each element of the job, using a stop watch.
   A stop watch may be of the following types;
      - ✓ Non fly back; recording continuous timing.
      - ✓ Fly back; the watch is started and stopped with the help of the slide.
      - ✓ Split hand; type of stop watch gives higher accuracy in reading when two elements are to be timed successively. As one element is completed, pressing the winding knob makes one hand to stop while the other hand keeps moving.

   e. Assess the effective speed of working of the operator with respect to the time study observer's concept of the speed of working of the qualified worker who is assumed to have a standard rating.

   Rating factor or levelling factor is determined by comparing the actual pace or speed of working (of the worker studied) with the standard pace or speed of working (of the qualified worker).

   f. Determination of normal or basic time:

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

$$= \text{Observed time} \times \frac{\text{(Observed rating)}}{\text{(Standard rating)}}$$

   g. Determine the relevant allowances: the time allowance to be given to the operator for relaxation, fatigue, contingency etc. Usually these allowances are taken as a percentage of basic or normal time.

The various types of allowances are: **(June 2015)**

- **a. Relaxation allowance (RA):** personal, fatigue on delay allowance (PFD allowance),
- **b. Contingency allowance (CA):** This allowance is given for infrequent or non-repetitive activities such as obtaining special materials from stores, sharpening of tools, getting a special tool from the tool stores, and consultation with the supervisor. It is usually about 5% of normal or basic time.
- **c. Process allowance:** Allowance given to the worker to compensate himself for enforced idleness due to the nature of a process or operation; for e.g., working on automatic machine, electroplating etc., during which the worker is forced to be idle during a part of the work cycle.
- **d. Special allowances:**

Standard time = Normal time + all relevant allowances.

$$NT = CT\ (PR)$$

Where, PR is the performance rating.

. standard time formula.

$$ST = NT\ (AF) \text{ where } AF = \frac{1}{1 - \%\ \text{Allowance}}$$

AF being the allowance factor.

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

2. **Synthesis Method; Synthesis** is a technique of work measurement for building up the time required to do a job at a defined level of performance by synthesising or totalling elemental time values obtained from previous time studies on other jobs containing similar job elements or from standard data or synthetic data or built-up time standards.

Applications of Synthesis Method;

a. To estimate standard time for new jobs.
b. To estimate production time for determining the prices of products to be sold.
c. Used as a basis for designing incentive schemes.

3. **Analytical Estimating;** This technique of work measurement is used to determine the lime values for jobs having long and non-repetitive operations

Applications of Analytical Estimating Technique

a. For non-repetitive jobs, jobs having long cycle times and jobs having elements of variable nature. For such jobs stop watch time study proves to be uneconomical.
b. For repair and maintenance work, job production, one time large projects, offer routines, tool room jobs and engineering construction works.

4. **Predetermined Motion Time System (PMTS);** Predetermined motion time system is defined as a work measurement technique by which normal or basic times are established for basic human motions and these time values are used to build up the time for a job at a defined level of performance.
5. **Work Sampling or Activity Sampling or Ratio-Delay Method;** Work sampling is a work measurement technique that randomly samples the work of one or more employees at periodic intervals to determine the proportion of total operations that is accounted for in one particular activity.

Uses of Work Sampling Technique;

1. To estimate the percentage of a protracted time period consumed by various activity states of a resource such as equipment, machines or operators.
2. To determine the allowances for inclusion in standard times.
3. To indicate the nature of the distribution of work activities within a gang operation.
4. To estimate the percentage of utilization of groups of similar machines or equipment.
5. To indicate how materials handling equipments are being used.
6. To provide a basis for indirect labour time standards.
7. To determine the productive and nonproductive utilization of clerical operations.

Steps in Work Sampling;

1. Determine the objective of the study, including definitions of the states of activity to be observed.
2. Plan the sampling procedure including:
   a. An estimate of the percentage of time being devoted to each phase of the activity.
   b. The setting of accuracy limits.
   c. An estimation of the number of observations required.
   d. The selection of the length of the study period and the programming of the number of readings over this period.
   e. The establishment of the mechanics of making the observations, the route to follow and the recording of data.
3. Collect the data as planned.
4. Process the data and present the results.

Principles Involved in Work Sampling; If we assume that C is a constant corresponding to confidence level, then values of C will be 1 for 68.3% confidence level, C=2 for 95.45% (or 95%) confidence level and C=3 for 99% confidence level. Then the number of observation needed for the work sampling study to get the result within an absolute error of

p = percentage or true proportion of activity or idling which is being observed based on pilot study

s = relative error of the true proportion 'p'

c = contact having values of 1, 2 and 3. corresponding to the confidence level of 68.3%, 95% and 99% respectively.

"Just-in-Time System"

- JIT was invented by Taiichi Ohno of Toyota
- Just-In-Time is defined as "the production of the minimum number of different units, in the smallest possible quantities, at the latest possible time, thereby eliminating the need for inventory"
- JIT is an operational philosophy which incorporates an improved inventory control system in conjunction with other systems
- The primary elements of JIT are to have only the required inventory when needed, to improve quality to zero defects, to reduce lead times by reducing set-up times, queue lengths and lot sizes, to incrementally revise the operations themselves and to accomplish these things at minimum cost.

JIT means

- ✓ Producing the quantity of units that is needed, no more, no less.
- ✓ Producing them on the date and at the time required, not before and not after.
- ✓ That a supplier delivers the exact quantity demanded, at the scheduled time and date.

Just-in-time Philosophy; JIT is a philosophy of continuous and forced problem solving. With JIT, supplies and components are "pulled" through a system to arrive where they are needed and when they are needed.

Concepts of JIT; The three fundamental concepts of JIT are :

i. Elimination of waste and variability;
   a. Waste Reduction; 'Anything that does not add value is described as waste in the production of goods or services. Moreover, any activity that does not add value to a product from the customer's perspective is waste. JIT speeds throughput, allowing faster delivery times and reducing work-in-process. Reduced work-in-process releases capital tied up in inventory for other more productive purposes
   b. Variability Reduction; Variability is any deviation from the optimum process that delivers perfect product on time, every time. Inventory hides variability or in other words problem The less variability in a system, the less waste in the system. Most of the variability is caused by tolerating waste or by poor management. To achieve just-in-time material movement, it is necessary that variability caused by both internal and external factors are reduced.
   Reasons for occurrence of variability are:
      - Employees, machines and suppliers, produce units that do not conform to standards, are late or are not the proper quantity.
      - Engineering drawings or specifications are inaccurate.
      - Production personnel try to produce before drawings or specifications are complete.
      - Customer demands are unknown.

   The JIT philosophy of continuous improvement removes variability, which allows movement of good materials just-in-time for use. JIT reduces materials throughout the supply chain.

ii. "Pull" versus "Push" system; Pull System is a concept that results in material being produced or supplied only when requested and moved to where it is needed just as it is needed. By pulling material through the system in very small lots, just as it is needed, the cushion of inventory that hides problems is removed, problems become evident and continuous improvement is emphasized.
   Push system is a system that pushes materials into downstream workstations, regardless of their timeliness availability of resources to perform the work. Push systems are the antithesis of JIT.

iii. Manufacturing cycle time (or "throughput" time); Manufacturing cycle time is the time between the arrival of raw materials and the shipping of finished products. JIT helps in reducing the manufacturing cycle time.

Romantic JIT and Pragmatic JIT; These are the two views of JIT;

a. Romantic JIT consist of various slogans and idealistic goals such as lot sizes of one, zero inventories and zero defects.
b. Pragmatic JIT on the other hand consist of a set of techniques, some fairly technical, that relate to machine changeovers, lay-out design, product simplification, quality training, equipment maintenance and so on.

Lean Production; Lean production is an assembly-line methodology developed originally for Toyota. Lean production principles are also referred to as lean management or lean thinking. It focuses on eliminating waste and empowering workers, reduced inventory and improved productivity

Little JIT and Big JIT;

Little JIT is a form of production scheduling and inventory management whereby products are produced only to meet actual demand, and materials for each stage of production are received or produced "justin- time" for use in the next stage of production or for delivery to a customer. This limited definition of JIT has been called Little JIT.

Big JIT (Lean Production) is the philosophy of operations management that seeks to eliminate waste in all aspects of a firm's production activities : human relations, vendor relations, technology and the management of materials and inventories.

Objectives of JIT Manufacturing; JIT tries to build only what internal and external customers want and when they want it. The more focussed objectives of JIT are:

a. Produce only the products (goods or services) that customers want.
b. Produce products only as quickly as customers want to use them.
c. Produce products with perfect quality.
d. Produce in the minimum possible lead times.
e. Produce products with features that customers want and no others.
f. Produce with no waste of labour, materials or equipment; designate a purpose for every movement to leave zero idle inventory.
g. Produce with methods that reinforce the occupational development of workers.

Overview of JIT manufacturing; JIT manufacturing includes many activities

I. Inventory reduction :
II. Quality improvement
III. Lead time reduction; With JIT, lead time components such as set-up and move times are significantly reduced.
IV. Vendor control/Performance improvement
V. Continuous Improvement: In the JIT system, existing problems are corrected and new problems identified in a never-ending: approach to operations management.
VI. Total Preventive Maintenance;
VII. Strategic Gain; JIT provides the firm's management with a means of developing, implementing and maintaining a sustainable competitive advantage in the market place.

Pre-requisites for JIT Manufacturing; Before implementing the JIT system, certain changes to the factory and the way it is managed must occur before the benefits of JIT can be realised. These changes are:

- Stabilise production schedules.
- Make the factories focussed.
- Increase production characteristics of manufacturing work centres.
- Improve product quality.
- Cross-train workers so that they are multi-skilled and competent in several jobs.
- Reduce equipment break downs through preventive maintenance.
- Develop long-term supplier relationships that avoid interruptions in material flows.

Characteristics of Just-in-Time System; JIT systems focus on reducing inefficiency and unproductive time in the production process to improve continuously the process and quality of the product or service. An outline of the salient characteristics of JIT are:

a) pull method of material flow
b) constantly high quality
c) small lot sizes
d) uniform workstation loads
e) standardised components and work methods
f) close supplier ties
g) flexible workforce
h) line flow strategy
i) automated production and
j) preventive maintenance.

Elements of a JIT Manufacturing System; The important elements or components of a JIT manufacturing system are:

- Eliminating waste
- Enforced problem solving
- Continuous improvement
- Involvement of people
- Total quality management and
- Parallel processing.

JIT Purchasing; The essentials of JIT purchasing are:

- ✓ Supplier development and supplier relation undergo fundamental changes.
- ✓ Purchasing departments develop long term relationships with few suppliers rather-than a short term relationship with many suppliers.
- ✓ Suppliers are encouraged to extend JIT methods to their own suppliers.
- ✓ Suppliers are ordinarily located near the buying firm's factory or clustered together at some distance which will keep the lead times shorter and more reliable.
- ✓ Shipments are delivered directly to the customer's production line usually through transportation vehicles owned by suppliers.
- ✓ Parts are delivered in small, standard size containers with a minimum of paperwork and in exact quantities.
- ✓ Delivered material is of near-perfect quality.

Productivity Management and Total Quality Management;

Productivity; Productivity is achieving the highest results possible while consuming the least amount of resources.
The term productivity can be defined in two ways. In simple terms, productivity is defined as a ratio between the output and input.

$$\text{Productivity} = \frac{\text{Output obtained}}{\text{Inputs consumed}}$$

In a broader sense, productivity is defined as a measure of how well resources are brought together in organizations and utilized for accomplishing a set of results.

$$\text{Productivity} = \frac{\text{Performance achieved}}{\text{Resources consumed}} = \frac{\text{Effectiveness}}{\text{Efficiency}}$$

- Accordingly performance refers to the "effectiveness" in reaching in mission or planned achievement or a needed value without serious regard to the costs incurred in the process.
- Efficiency refers to how well these resources are brought together for achieving results with minimum costs.

$$\text{Effectiveness} = \frac{\text{Target achieved}}{\text{Target achievable}}$$

- Organizational effectiveness means the degree or the extent to which the targets of an organization are achieved.

Kinds of Productivity;

1. Partial Productivity; This measures productivity of one factor or input, keeping other factors or inputs constant or unchanged. These measure the change in output with respect to labour and capital, one at a time respectively, keeping in other constant.
2. Total Productivity: Here, productivity is calculated with respect to the total cost or the total finances committed, instead of one input, as given below:

$$\text{Productivity} = \frac{\text{Value added}}{\text{Total factor cost}} = \frac{\text{Value of gross output}}{\text{Total value of inputs.}}$$

The total factor productivity (TFP) is a measure of the overall changes in production efficiency.

Measuring Productivity; Good productivity measure should possess the following properties;

a. **Validity:** it reflects accurately the changes in productivity.
b. **Completness:** It takes into consideration all components of both the output and the input for a given productivity ratio.
c. **Comparability:** It enables the accurate measurement of a productivity change between periods.
d. **Inclusiveness:** It takes into account and measures separately all activities.
e. **Timeliness:** It ensures that data is provided soon enough for managerial action to be taken when problems arise.
f. **Cost effectiveness:** It obtains measurement in a manner that will cause the least interruption possible to the ongoing productive efforts of the firm.

Models of Productivity Measurement –These models can be classified into three.**(Dec 2013)**

a. Ratio method;
   i. The definition of output; Output has been defined in more than one way.
      - ✓ Gross or total output
      - ✓ Net output or value added
   ii. One input partial productivity measure; and (Partial Productivity)
   iii. Many input total productivity measure. (Total Productivity)
b. Production Function Method;
c. Performance – Objective – Productivity (P-O-P) Approach; Sardana and Vrat (1984) have used the P-O-P approach. According to this;

$$\text{Productivity Index} = \frac{\text{Performance in m activities over n functional sub-system}}{\text{performance objectives in m activities over n functional sub-system}}$$

Need for Productivity Improvement; In business, improved productivity may lead to:

1. Better consumer service through lowering of prices;
2. Increased cash flows, improved return on assets, and greater profits;
3. Increased profits that would enhance stock price substantially;
4. Increased profits that would lead to expansion of capacity and creation of new jobs;
5. Greater investment in R/D and development of new products; and
6. Better living standards. "Economists do not agree on many things, but all agree that improved living standards are dependent absolutely on increasing productivity."

Factors Affecting Productivity; The factors affecting productive efficiency are listed below along with corresponding productivity tools.

Productivity factors	Productivity tools
Plant/Organisation	
Top management planning	Plant policy
Management and supervision	Organisation chart
Co-ordination and cooperation	Organisation manual
Internal communications	Human relations studies
	Joint consultation
	Mutual trust and co-operation
Internal communications	Management reports, Management audit.
Products	
Product selection	Operation research
Product quality	Product planning
	Statistical quality control
Product programme	Product research
Product design	Specialisation
Product packaging	Standardisation
	Simplification
Physical Facilities	
Plant capacity	Plant labour techniques
Plant location	Mechanisation
Plant building	Automation
Plant equipment	Human engineering
Plant installation	Preventive maintenance
Personnel	
Selection	Job analysis
Employment	Job evaluation
Training	Merit rating
Safety	Accelerated training
Wage payment	Works measurement
Production	
Manufacturing	Budgeting
Assembly	Production-engineering
Sales	Production planning
Distribution	Predetermined Motion Standard
	Materials control
	Materials handling
	Work simplification
	Activity sampling

Kaizen;

KAIZEN is Japanese word made up of KAI and ZEN. KAI means change and ZEN means better. Thus KAIZEN means change for the better. It implies continuous improvement done consistently. KAIZEN diagnoses the major root causes of inefficient working in the organisation and offers a systematic approach to change the attitudes of people for increasing productivity, improving quality and thus leading to miraculous organizational change. The essence of
KAIZEN is simple and straight forward, i.e. "on going improvement involving everyone including both managers and workers". KAIZEN signifies productivity improvement made in the status-quo as a result of on-going efforts.

The KAIZEN simply means improvements, on-going improvements involving every one in the organisation from door-man to the chairman.

Motivational implications of KAIZEN Technique Implementation; (Jan 2016) The KAIZEN gives freedom to the employees. It does not specify what changes are to be made or how many of them are to be made. Improvements can be in any discipline and in any field of human activity related to the productivity. These decisions are left to the individuals. This leads to obvious **advantages as follows; (Dec 2013)**

a. The first and foremost benefit of KAIZEN is that it brings about changes in attitude among employees towards improvements of their routine work. Hence it increase the productivity and a new work culture is created in the organisation.
b. Once the culture is transformed, the way gets cleared for introducing other productivity improvement systems like JIT, KANBAN etc. obviously leading to productivity improvement.
c. KAIZEN system reduces resistance to change.
d. Ownership of work improves in KAIZEN environment. It is the inner voice of the employees that drives them to make the improvements, rather than the orders given down through the hierarchy.

Role of Information Technology in Production/Operations Management; Information technology is crucial to operations everywhere along the supply chain and to every functional area. Computer based information technology, in particular, has greatly influenced how operations are managed and how offices work. It makes cross-functional coordination easier and links a firm's basic processes. In a manufacturing plant, information technologies can link people with the work centres, data bases and computers.

Components of Information Technology; Information technology is made up of four sub-technologies.

1. Hardware
2. Software
3. Database and
4. Telecommunications

Technology Fusion; Technology fusion refers to the process of combining several current technologies and scientific knowledge to create a **hybrid technology.** Adding one technology to another results in synergic effects. For example, in machine tool industry NC, CNC machines are the result of fusion of electronics and mechanical technologies.

Technology Choice; The choice of technology should not only consider net present value of the investment made but also the effects on customers, employees and the environment. When technological alternatives are evaluated, they should be considered with respect to the do-nothing alternative.

Technology Integration; concurrent engineering to bridge the gap between R & D, product development and manufacturing. This approach is referred to as "technological integration"

Technology and Cost Minimisation; Technology has a great impact on cost minimization. Improvement of technology leads to hi-tech production facility which helps in mass production, that results in economies of scale. Technology also improves the quality of input and it results in flawless production. It also reduces the cost of error detection and rectification to a large extent. Improved technology brings automation and reduces the requirement of excess manpower, hence results in low cost of production. Automation speeds up production and results in increase of scale of production in a given period. Updated and newer technology also helps an organization by minimising the supply and distribution expenses. On the other hand improved and unique technology helps in creation of core competency. A better technological approach thus supports in many ways to achieve cost minimization.

Quality Circles;

Definition; According to the Union of Japanese Scientists and Engineers (JUSE) "Quality Circle is a small group formed to perform voluntarily QC activities leading to self development within the work place".

Quality circle is a small group of employees who voluntarily meet together regularly to identify, analyse and solve the work related problems (Quality, wastage, productivity, housekeeping, safety, communications etc.)

Objectives; Quality circles adoption leads to benefits (A) Individual and (B) Organizational.

A. **Benefits for the Individual;**
   i. Personality Development.
   ii. Mutual Development.
   iii. Job Satisfaction.
   iv. Problem Solving Capability.
   v. Togetherness
   vi. Better Human Relationship.
   vii. Exchange of Good Thoughts.
   viii. Orating Capability (Stage openings).

B. Benefits for an Organization;
   i. Improves Productivity.
   ii. Improves Quality of Product.
   iii. Reduces Wastage.
   iv. Increases Employee Motivation.
   v. Inspires more Effective Team Work.
   vi. Develops harmonious Superior-Subordinate Relationship.
   vii. Improves communication within Organizations.
   viii. Develops a complete coherent problem Solving Environment.

Structure of QC; The success of a QC mainly depends upon the structure and the main feature of a QC principle lies in that form top management to a small worker are tied up. The following basic elements constitute the structure of a QC :

i. Top Management.
ii. Steering Committee.
iii. Co-ordinating Agency;
iv. Facilitates;
v. Leaders/Deputy Leaders;
vi. Members.

Quality Circle Technique;

1. Team is necessary for QC to adopt following technique in order to smooth working of QC.
2. Pareto Principle; According to Pareto, the important cause are always quite less in number QC focuses it's attention on these less but important problems. According to this principle if 80% of accidents are occurring in 20% of factory then 20% factories are having unsafe working procedures.
3. Collection of Data
4. Analysis of Problem
5. Problem Selection and Solution
6. Presentation to Management
7. Code of Conduct.

Total Quality Management;

What is Quality?

- ✓ Conformance to specifications;
- ✓ Conformance to requirements;
- ✓ What the customer thinks it is;

- ✓ Measure of the conformance of the product/service to the customer's needs;
- ✓ Combination of aesthetics, features and design;
- ✓ Value for money;
- ✓ The ability of a product to meet customer's needs;

Eight Dimensions of Product Quality;

1. Performance 2. Features 3. Reliability 4. Serviceability 5. Aesthetics (appearance) 6. Durability 7. Customer service 8. Safety

Ten Dimensions of Service Quality

1. Reliability 2. Responsiveness 3. Competence 4. Access 5. Courtesy 6. Communication 7. Credibility 8. Understanding 9. Security/Safety 10. Tangibles.

Benefits of Quality

1.	Gives positive company image.	2.	Improves competitive ability.
3.	Increases market share and net profits.	4.	Reduces costs.
5.	Reduces product liability problems.	6.	Improves employee morale.
7.	Improves productivity.		

Perceived Quality: "An assessment of quality based on the reputation of the firm." Customers base their assessment of quality on such factors as advertisements, media reports, reputations and past experience to indicate perceived quality.

Three Levels of Quality

1.	Organisation level	Meeting external customer requirements
2.	Process level	Meeting the needs of internal customers
3.	Performer level (job level or task design level)	Meeting the requirements of accuracy, completeness innovation, timeliness and cost.

Quality Control; Quality control begins with product design and includes materials, bought-out items, manufacturing processes and finished goods at the hands of customers. Quality control aims at prevention of defects rather than detection of defects (by inspection) Objectives of quality control is to provide products/services which are dependable, satisfactory and economical.

What is Quality Control?

1. Setting quality standards (objectives or targets)
2. Appraisal of conformance (quality measurement)
3. Taking corrective actions to reduce deviations
4. Planning for quality improvement

Quality & Reliability; Reliability is the probability of performing without failure, a specified function under given conditions for a specified period of time.

Company-Wide Quality Control (CWQC) : System of activities that assume that quality products and services required by customers are economically designed, produced, and supplied involving all departments of an organization.

Quality Assurance : All activities required to ensure that the product performs to the customers' satisfaction.

Quality Improvement: Finding ways to do better than standard and breaking-through to unprecedented levels of performance. It is the responsibility of those who produce the products and not of inspectors, (i.e., quality at the source).

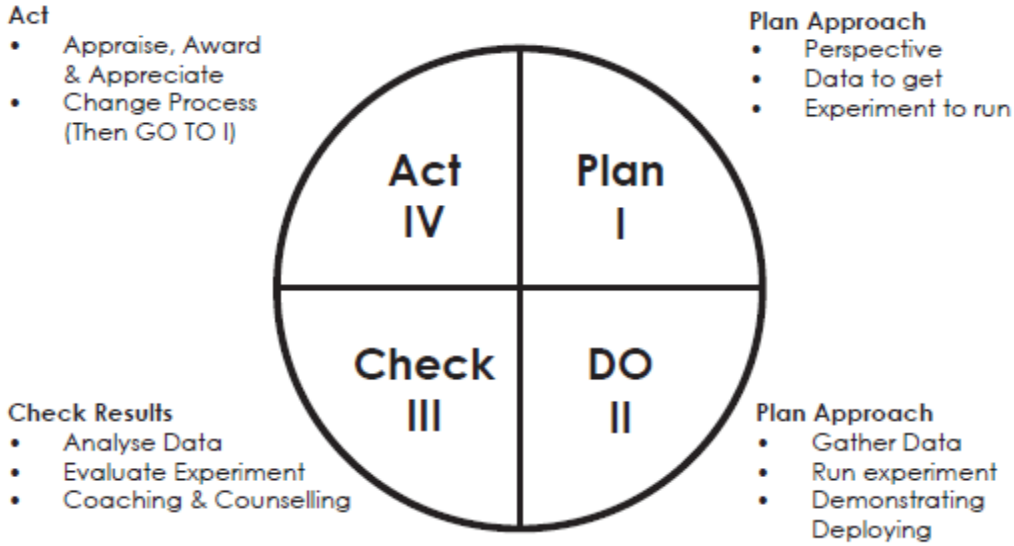
Principles of Total Quality; (Dec 2013)

- Focus on the customer (Both internal & external)
- Participation and team work
- Employee involvement and empowerment
- Continuous improvement and learning.

Total Quality Control; It is an effective system for **integrating quality development, quality maintenance and quality improvement efforts of various groups in an organisations.**

Principles of Total Quality Control (TQC); (June 2015)

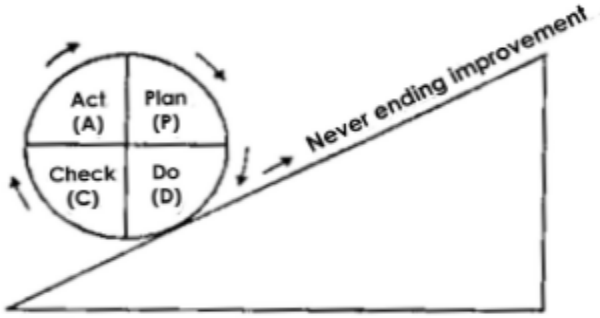
1. Top management policies - Zero defects, continuous improvement etc;
2. Quality control training for everyon;
3. Quality at product/service design stage;
4. Quality materials from suppliers;
5. Quality control in production (SQC);
6. Quality-control in distribution, installation and usg;



: The deming cycle.

Deming Wheel/Deming Cycle/P-D-C-A Cycle

P - Plan (process) the improvement
D - Do Implement the plan
C - Check - Check how closely result meets goals
A - Act - Use the improved process as standard practice



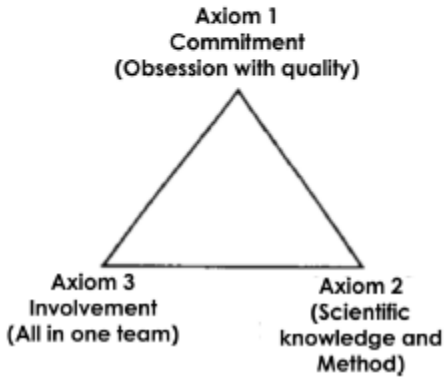
Deming's Triangle (3 Axioms)

Axiom 1 : Commitment (Obsession with quality)

Axiom 2 : (Scientific Knowledge & Method)

Axiom 3 : Involvement (All in one team)

Deming Prize : Awarded by the union of Japanese Scientists and Engineers (JUSE) to a firm or its division based on the distinctive performance improvements achieved through the application of Company Wide Quality Control (CWQC).



Cost of Quality;

1. **Prevention costs:** Costs of quality planning, new product review, training, process planning, quality data and improvement projects.
2. **Appraisal costs:** Costs of incoming inspection, process inspection, finished goods inspection, quality laboratories and calibration of instruments.
3. **Internal failure costs:** Costs of scrap, rework, down grading (seconds quality products) retest, downtime.
4. **External failure costs:** Costs of warranty, returned goods, customer complaints, allowances to customers for substandard quality products.

Costs of quality can be reduced by revising the production system including technology, management, attitudes and training.

Quality Triology

(i) Quality planning, (ii) Quality control and (iii) Quality improvement.

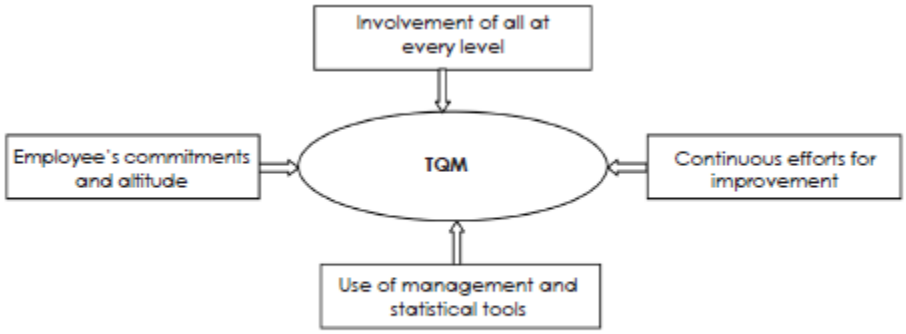
Total Quality Management;

Meaning; Total Quality Management (TQM) consists of organization-wide efforts to install and make permanent a climate in which an organization continuously improves its ability to deliver high-quality products and services to customers. TQM improves productivity and competitive advantage.

TQM is a vision based, customer focused, prevention oriented, continuously improvement strategy based on scientific approach adopted by cost conscious people committed to satisfy the customers first time every time. It aims at Managing an organization so that it excels in areas important to the customer.

The elements of TQM are:

Total	Quality involves everyone and all activities in the company (Mobilizing the whole organization to achieve quality continuously and economically)
Quality	Understanding and meeting the customers' requirements. (Satisfying the customers first time every time)
Management	Quality can and must be managed (Avoid defects rather than correct them)

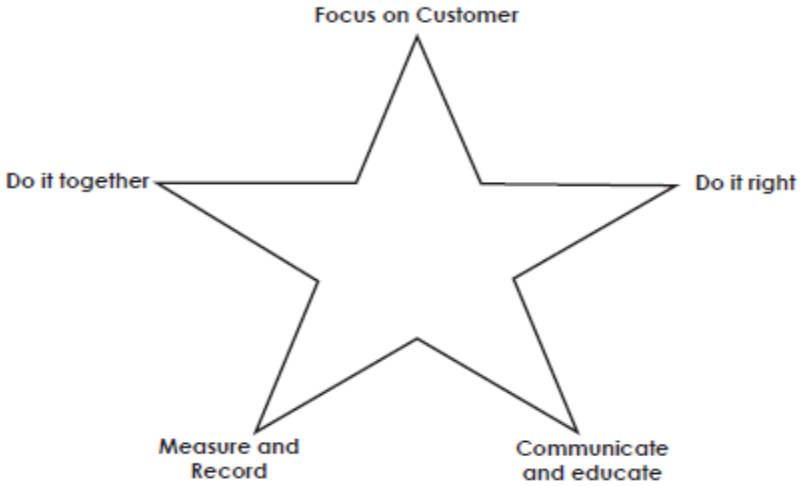


Elements of Total Quality Management

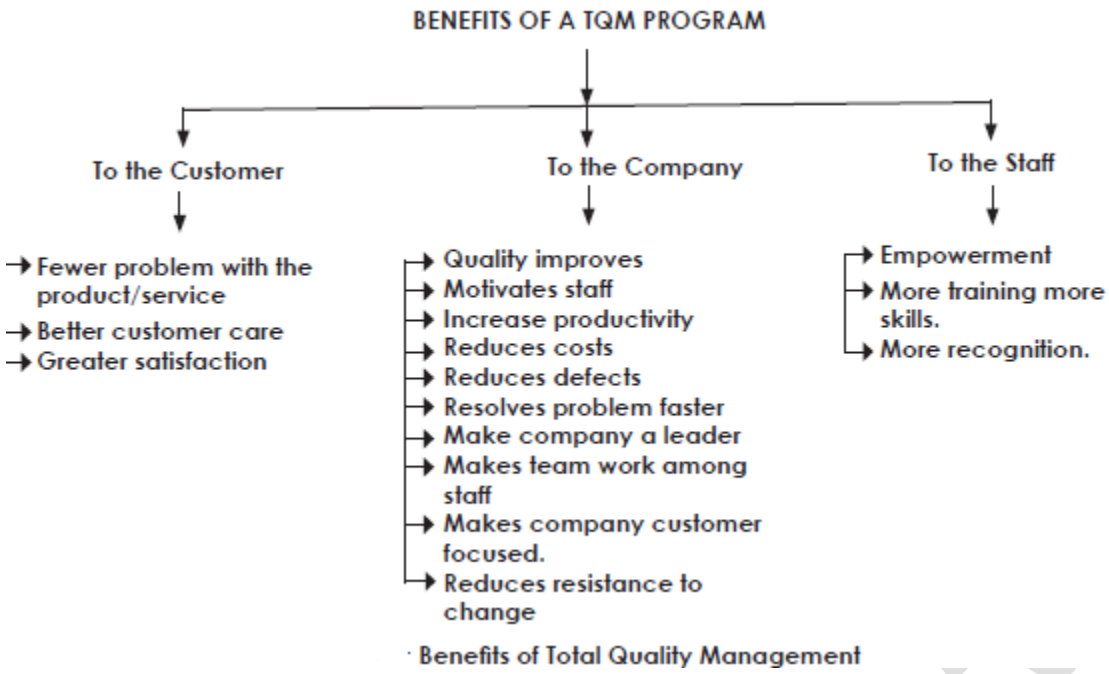
Basic Approach; TQM requires six basic concepts;

1. A committed and involved management to provide long-term top-to-bottom organizational support.
2. An unwavering focus on the customer, both internally and externally.
3. Effective involvement and utilization of the entire work force.
4. Continuous improvement of the business and production process.
5. Treating suppliers as partners.
6. Establish performance measures for the processes.

THE FIVE PRINCIPLES OF TQM



Principles of Total Quality Management



Benefits of Total Quality Management

Six Sigma;

Six Sigma at many organizations simply means a measure of quality that strives for near perfection. Six Sigma is a disciplined, data-driven approach and methodology for eliminating defects (driving toward six standard deviations between the mean and the nearest specification limit) in any process – from manufacturing to transactional and from product to service.

- ✓ A Six Sigma defect is defined as anything outside of customer specifications
- ✓ To achieve Six Sigma, a process must not produce more than 3.4 defects per million opportunities.

Four Phase Approach; Six Sigma will follow a four phase approach:

1. **Measure** - Determine the error or defect rate
2. **Analyze -** Understand the Process
3. **Improve -** Reach for a higher Sigma
4. **Control -** Monitor through measurement

Six Sigma projects follow two project methodologies inspired by Deming's Plan-Do-Check-Act Cycle. These methodologies, composed of five phases each, bear the acronyms DMAIC and DMADV.

One key innovation of Six Sigma involves the "professionalizing" of quality management functions. Formal Six Sigma programs adopt a ranking terminology (similar to some martial arts systems) to define a hierarchy (and career path) that cuts across all business functions.

Benchmarking;

Benchmark: A measure, "best-in-class" achievement; a reference or measurement standard for comparison;

Benchmarking:

Meaning: Benchmarking is the continuous process of measuring products, services or activities against the best levels of performance that may be found either inside or outside the organization. It is a process of comparing a firm's activities with best practices.

Benefits of Benchmarking;

- Benchmarking is particularly helpful in validating proposals for change.
- Benchmarking of ten results in creative imitation and the adoption of new practices that overcome previous industiy barriers.
- This search for diversity and for innovative breakthroughs applied elsewhere is at the core of benchmarking benefits.
- By sharing information, all parties benefits, because it is difficult to excel in all activites.
- Sharing information and data is often the first hurdle to be overcome in the Benchmarking process.
- If the search for "Best", or just "Better" practices is performed correctly, then the likelihood of successful outcomes is quite high.

Eight Most Common Benchmarking Errors; **(Dec 2014 – 8 Mark)**

1. Lack of Self-Knowledge,
2. Selective
3. Benchmarking projects are broad instead of focused.
4. Benchmarking produces reports, not action.
5. Benchmarking is not continuous.
6. Looking at the numbers,
7. Participants are not motivated.
8. Too much data.

Common Pitfalls in Benchmarking

- Lack of management commitment and involvement.
- Not applied to critical areas first
- Inadequate resources.
- No line organisation involvement.
- Too many subjects ; scope not well defined.
- Too many performance measures.
- Critical success factors and performance drivers not understood or identified.
- Potential partners ignored : Internal organisations, Industry leaders, or friendly competitors.
- Poorly designed Questionnaires,
- Inappropriate data : Inconsistent data.

Eight Benchmarking Process; (Dec 2015)

Planning:	1.	Select Benchmarking subject and appropriate team
	2.	Identify performance indicators and Drivers
	3.	Select Benchmark partners
	4.	Determine data collection method and collect data
Analysis :	5.	Analyse performance gaps.
Integration	6.	Communicate Findings and identify projects to close gaps
Action :	7.	Implement plans and monitor results !
	8.	Recalibrate benchmarks.

Relationship between R&D Inputs and Output (Dec 2013)

Some important variables determining R & D efforts and its success have been identified as follows:

(i) The size of the operation has been found to be positively related to the success of R & D.
(ii) The presence of technological opportunities in the industry leads to better R & D efforts.
(iii) The philosophy and genuine efforts of the management are necessary for successful R & D efforts.
(iv) The contribution of individual researchers to R & D has been found to be quite substantial.
(v) R & D efforts are likely to be more effective where growth prospects are good and profits are likely to be high.
(vi) Diversification is positively related to the R & D efforts, as there is scope of their utilization.
(vii) A number of studies have suggested a strong relationship between R & D and the marketing opportunities for a new product. Market opportunities have been found to contribute three times more than technical opportunities as sources for innovations.

Implementation of ISO- 9000; (June 2014)

1. Senior Management Commitment.
2. Appoint the Management Representative.
3. Awareness
4. Appoint an Implementation Team.
5. Training
6. Time Schedule.
7. Select Element Owners.
8. Review the Present System.
9. Write the Documents.
10. Install the New System.
11. Internal Audit.
12. Management Review.
13. Pre-assessment
14. Registration

Four generic components of Technology Innovation; (Dec 2014)

1. Basic research is research for the advancement of scientific knowledge that has no specific commercial uses. Basic research may, however, be in the field of present or potential interest to the company.
2. Applied research is research for the advancement of scientific knowledge that has specific potential commercial uses.
3. Development is technical activity concerned with translating basic or applied research results into products or processes.
4. Implementation is activity concerned with designing and building pilot models, equipment, and facilities, and initiating the marketing channels for products or services emerging from research and development.

Maintenance and Spares Management;

Maintenance is defined as "that function of production management that is concerned with the day to- day problem of keeping the physical plant in good operating condition.

Maintenance Management; It is a function supporting production function and is entrusted with the task of keeping the machinery/equipment and plant services in proper working condition. It also involves maintenance planning, maintenance scheduling, execution of maintenance activities (repair, breakdown and preventive maintenance) and also controlling costs of maintenance.

Scope of Maintenance;

a. Primary Functions;
   i. Maintenance of existing plant and equipments.
   ii. Maintenance of existing plant buildings and grounds.
   iii. Equipment inspection and lubrication.
   iv. Utilities generation and distribution.
   v. Alterations to existing equipments and buildings,
   vi. New installations of equipments and buildings.
b. Secondary Functions;
   i. Storekeeping (keeping stock of spare parts)
   ii. Plant protection including fire protection.
   iii. Waste disposal.
   iv. Salvage
   v. Insurance administration (against fire, theft, etc.).
   vi. Janitorial services.
   vii. Property accounting
   viii. Pollution and noise abatement or control.

Objectives of Maintenance Management;

1. Minimizing the loss of productive time because of equipment failure
2. Minimizing the repair time and repair cost.
3. Minimizing the loss due to production stoppages.
4. Efficient use of maintenance personnel and equipments.
5. Prolonging the life of capital assets by minimizing the rate of wear and tear.
6. To keep all productive assets in good working condition.
7. To minimize accidents through regular inspection and repair of safety devices.
8. To improve the quality of products and to improve productivity.

Areas of Maintenance;

1. Civil Maintenance; Building construction and maintenance
2. Mechanical Maintenance; Maintaining machines and equipments
3. Electrical Maintenance; Maintaining electrical equipments

Types of Maintenance;

i. Breakdown maintenance or corrective maintenance; occurs when there is a work stoppage because of machine breakdown. Corrective maintenance seeks to achieve the following objectives;
   a. To get equipment back into operation as quickly
   b. To control the cost of repair crews, including regular time and overtime labour costs.
   c. To control the cost of the operation of repair shops.

ii. Preventive maintenance; aims to minimise the possibility of unanticipated production interruptions. It consists of;
   a. Proper design and installation of equipment,
   b. Periodic inspection of plant and equipment to prevent break downs before they occur,
   c. Repetitive servicing, upkeep and overhaul of equipment, and
   d. Adequate lubrication, cleaning and painting of buildings and equipment.

iii. Predictive maintenance; In this, sensitive instruments (e.g., vibration analysers, amplitude meters, audio gauges, optical tooling, pressure, temperature and resistance gauges) are used to predict trouble

iv. Routine maintenance,; periodic ; Routine maintenance may be classified as :
   a. Running maintenance
   b. Shut down maintenance; equipment is out of service
v. Planned maintenance; predetermined schedule;

Requirement of a Good Preventive Maintenance Program;

1. Good supervision and administration of maintenance department.
2. A good lubrication schedule.
3. Consultation with production department personnel before fixing priority schedules for maintenance work.
4. Clear, correct and detailed instruction to maintenance crew regarding maintenance work.
5. Adequate stock of spare parts recommended by equipment manufacturers.
6. Proper training for maintenance crew.
7. Adequate space around the machine for ease of maintenance work.
8. Data regarding failure of machines and the corrective maintenance work carried out earlier.

Steps in Preventive Maintenance Programme; ;

1. Job identification or preparing facility register
2. Preparation of preventive maintenance schedule
3. Preparation of history card
4. Preparation of job specification
5. Preparation of preventive maintenance program
6. Preparation of preventive maintenance schedule (weekly or monthly):
7. Preparation of inspection report:
8. Preparation of maintenance report
9. Feed back mechanism

Advantages of Preventive Maintenance;

a. Increase in life of machines and equipments by reduction of wear and tear.
b. Reduction in frequency of breakdowns.
c. Improvement in productivity due to lesser machine down-time and consequent loss of production.
d. High reliability of production system due to lesser breakdown and repairs.
e. Higher worker safety while using the plant and equipment.
f. Planned shutdowns and start-ups of plant and equipment possible.
g. Lesser rejection and better quality control.
h. Less serious consequences of breakdowns and lesser breakdown maintenance costs.

Limitations of **Preventive Maintenance;**

a. More expensive in the short term and during the initial stages of introduction of preventive maintenance programme.
b. Inspection of plant, equipment and machinery will have to be carefully planned and implemented and improved over a period of time.

Total Productive Maintenance; TPM aims at "Zero breakdown" or "Zero down time".

Total Productive Maintenance (TPM) is an approach which brings the concept of total quality management in the practice of preventive maintenance. It involves the concept of reducing variability through employee involvement and excellent maintenance records.

Total productive maintenance is a method designed to eliminate the losses caused by breakdown of machines and equipments by identifying and attacking all causes of equipment breakdowns and system down-time

Specific actions of TPM require the following :

a. restoring equipment to a like-new condition,
b. having operators involved in the maintenance of the equipment or machine,
c. improving maintenance efficiency and effectiveness,
d. training the labour force to improve their job skills,
e. the effective use of preventive and predictive maintenance technology.

Total in "Total Production Maintenance" means

a. Total employee involvement,
b. Total equipment effectiveness (i.e., Zero breakdown) and
c. Total maintenance delivery system.

Guiding Principles of TPM Programs;

I. Maximise equipment effectiveness by reducing down time to zero
II. Establish a thorough system of preventive maintenance for entire life span of equipment from design and acquisition to disposal.
III. Implement maintenance program in all organizational areas such as engineering, operation, facility management and maintenance, to spread TPM through the system.
IV. Involve every single member of the organisation from top managers to workers on the shop floor.
V. Assign responsibility for preventive maintenance to small, autonomous groups of employees rather than managers.

Total productive maintenance is also known as **total preventive maintenance** which includes three main elements;

a. Regular preventive maintenance including house-keeping,
b. Periodic pre-failure replacement or overhauls, and
c. Intolerance for breakdowns or unsafe conditions.

Forecasting;

Forecasting is important to production and operations management in a number of decisions; to make an annual plan of production/ operations, to make a weekly or daily schedule of production or service operations, to procure or manufacture the raw materials or components and to plan the manpower, requirement amongst various other things. Forecasting, which involves a study of the present and past date with a view to estimate the future activities, forms the basis of planning.

Principles of Forecasting;

i. Forecasts are rarely perfect
ii. Forecasts are more accurate for grouped data than for individual items
iii. Forecast are more accurate for shorter than longer time periods

Steps in the Forecasting Process;

a. **Determine the purpose of the forecast**.
b. **Establish a time horizon.** The forecast must indicate a time interval, keeping in mind that accuracy decreases as the time horizon increases.
c. **Obtain, clean, and analyze appropriate data;** Obtaining the data can involve significant effort. Once obtained, the data may need to be "cleaned" to get rid of outliers and obviously incorrect data before analysis.
d. **Select a forecasting technique.**
e. **Make the forecast.**
f. **Monitor the forecast.** A forecast has to be monitored to determine whether it is performing in a satisfactory manner. If it is not, reexamine the method, assumptions, and validity of data, and so on; modify as needed; and prepare a revised forecast.

Advantages of Forecasting;

- Past data provides guidance for future and is a tool to train. Forecasts based on past data helps in correct planning.
- Forecasting of customer's demand help in strategy planning, capacity planning, location planning and layout planning.
- Past data provides trends, which are used to forecast the future trends and helps to decide on products or services pursued or to be stopped or abandoned.
- Forecast of manufacturing is essential to ensure the availability of materials for sub-assemblies and final assemblies.
- Forecasting helps in optimizing various costs as it lays down benchmarks to control the project.
- Forecasting by specifying future demands reduce the costs of readjustment of operations in response to the unexpected deviation.
- Accurate estimation of future demands of goods and services through forecasting increases the operating efficiency.
- Forecasting is an important component of strategic and operational planning.
- Utilization of the plant is improved with correct forecasts.

A. Forecast Error; **(Dec 2013)** The gap between forecasted demand and actual demand. It is desirable that the difference between forecasted and actual demand is low as possible. There are two measures of error as stated below.

1. **Mean Absolute Deviation (MAD):** MAD is the ratio of sum of absolute deviations for all periods to the total number of periods studied. Mean Absolute Deviation (MAD) is an average of the number of deviations recorded without considering the sign. It is represented as below:

$$MAD = \frac{\text{Sum of absolute values of deviations for all periods}}{\text{Total number of periods studied}}$$

$$= \frac{\sum_{i=1}^{n} \left| \text{Forecasted demand} - \text{Actual demand} \right|_i}{n}$$

2. **Bias:** Bias is worked out by using algebraic difference between forecasted and actual demands for all the periods. The algebraic differences are summed up and divided by the total number of periods studied. Bias indicates the directional tendency of the forecast errors.

Bias is represented as:

$$\text{Bias} = \frac{\text{Sum of algebraic errors for all the periods}}{\text{Total number of periods studied}}$$

$$= \frac{\sum_{i=1}^{n} (\text{Forecasted demand} - \text{Acutal demand})_i}{n}$$

The ideal forecast should have zero MAD and zero Bias. Usually tread off is attempted between MAD and Bias i.e., one must be kept low at the cost of the other. In general, focus should be on MAD. Lowering MAD to or near zero will automatically hold Bias low.

1.

The demand for sewing machine was estimated as 1000 per month for 5 months. Later on the actual demand was found as 900, 1050, 1000,1100 and 950, respectively. Workout MAD and Bias. Analyze whether the forecast made was accurate.

Essential for Effective Forecast;

- It should be accurate enough to help the decision making process.
- It should provide timely indications of major shifts in process performance.
- It should be simple to use.
- It should be easily understandable.

B. **Tracking Signals (TS);** Tracking Signal (TS) is calculated to indicate the deviations in cases where cumulative actual are either above or below the forecast by a substantial amount. The TS indicates the direction of the forecasting error, if TS is positive – increase the forecasts, but if it is negative – decrease the forecasts. It is the ratio of the cumulative algebraic sum of the deviations between the forecasts and the actual values to the mean absolute deviation. Tracking Signals are often used to monitor the forecasts especially when the overall forecast is suspect. If the TS is around zero, the forecasting model is performing well. A forecast is considered out of control, if the value of Tracking Signal exceeds plus or minus 4.

Mathematically, Tracking Signal is presented as below:

$$\text{Tracking Singals (TS)} = \frac{\text{Algebraic sum of deviations}}{\text{Mean Absolute Deviations (MAD)}}$$

$$= \sum_{i=1}^{n} \frac{(\text{Actual demand}_i - \text{Forecast demand}_i)}{\text{MAD}}$$

Forecasting Approaches;

A. Qualitative Approaches; Frequently used for longer range strategic planning and facilities decision. Qualitative approaches include five forecasting techniques:

a. Grass-root Forecasting; People at the grass-root level in the organization, who are in direct contact with the phenomenon under study, are asked to give inputs in forecasting.
b. Focused Forecasting; This method integrates common sense, grass-root inputs and computer simulation processes to assess the forecasts.
c. Historical Analogy; Information of past events is used to give insights into prediction on related future developments. It is assumed that the future events would follow similar pattern as the of the past events.
d. Panel Consensus; A group of knowledgeable persons are invited for an open discussion on a topic selected for forecasting. It is believed that a single person might not be able to consider all the aspects on the topic.
e. Delphi Method; A number of experts associated with the subject is asked to give their response to pre-selected questions, which would help in forecasting. The experts could be persons from within the organization or from outside the organization.

As the experts come from diverse backgrounds, they look at the issue independently from their own perspectives. On getting the feedback, they are able to appreciate the views of the experts from other expertise fields

also. This gives them better understanding of the issue. The result of Delphi is arrived by pooling up the knowledge of various experts and brings very good results.

Merits of Delphi;(Dec 2013) Delphi is preferred for the following reasons:

a. It involves knowledgeable persons on the subject.
b. Members in Delphi exercise come from different backgrounds and therefore the method is able to consider and pool up various aspects of the issue.
c. Since the members do not meet each other, their views are not influenced by the views of others.
d. No conflict of personality is seen in the process.
e. No dominance by any influential expert on the other experts.
f. It gives quick results as compared to quantitative techniques and helps in timely decisions.

Demerits of Delphi; The approach also has disadvantages as at times the experts take too much time in giving responses. It also becomes a disadvantage when serious treatment is not given to the questionnaire, while giving their responses.

B. Quantitative Forecasting; Quantitative forecasting techniques use the past numerical data for forecasting the future events. Frequently used for short-term operational planning such as production and inventory control The quantitative techniques use time series, which includes the following: This approach uses more of an analytical method like time series analysis model.

a. Simple Average;
b. Simple Moving Average;In this method, the number of past periods is selected. The average of the selected number of periods is calculated instead of average of all the periods taken together. In this case, the average is changing as we move forward and reflects the demand of the recent period more closely. As the one period elapses, the demand for the oldest period is not counted and the demand for the most recent period is added for the next calculation.
c. Weighted Moving Average; In case the planner wants to give different weights to different periods, he could use weighted moving average method by incorporating some weight for old demand instead of equal weightage for all past periods under consideration.
d. Exponential Smoothing; In this method, the demand for the most recent period is weighted most heavily and the weights of just preceding periods are lowered exponentially. This method cannot be used for an item, which has trend or seasonal pattern. This is best suited for independent demand with no trend and seasonality

Forecasting Methods; Forecasting Methods can be classified into;

i. Time series methods;
ii. Casual methods and
iii. Opinion-based methods.

A. Time series methods; In terms of time, the past data can vary over time due to
   - ✓ Random errors,
   - ✓ Underlying trend,
   - ✓ Seasonality, and
   - ✓ Cycles.

Smoothing Methods;

1. Moving Averages; A simple moving average involves taking a simple arithmetical average of a set of observed values, from the present time period to a certain time period in the past, and then using that average as the forecast for the time period in the immediate future.
2. Weighted Moving Averages ; Already Covered
3. Exponential Smoothing; Already Covered

Curve Fitting; Curve fitting is the process of finding a linear or non-linear, relationship between the dependent variable (which is usually the demand in forecasting) and an independent variable. We shall take up the least squares method of curve fitting.

Casual Methods; the causal methods try to identify the factors which cause the demand to vary and try to fit a relationship between the demand and these factors. For example, the increase in demand for an item may be related to the increase in population or in disposable income per household. It may also be related to the amount of competition in an inverse or negative way. Some of the causal methods are:

a. Regression and correlation analysis ;(Dec 2014) Regression analysis identifies the movement of two or more interrelated series. It is used to measure the changes in a variable (dependent variable) as a result of changes in other variables (independent variables).
   Correlation - If all the values of the variable satisfy a regression equation exactly, then the variables are said to be perfectly correlated. But, this is mostly not the case and the data points are scattered about the line (or plane) which is fitted to the data. In all such cases we need to describe the fit with a measure of correlation.
b. Econometric models (Out of Syllabus)
c. Input-output analysis (Out of Syllabus)
d. End-use analysis (Out of Syllabus)

Simulation;

In general terms, simulation involves developing a model of some real phenomenon and then performing experiments on the model evolved. In general, simulation aims to determine how the system under consideration would behave under certain conditions.

Process of Simulation; Broadly there are four phases of the simulation Process;(Dec 2015)

i. Definition of the problem and statement of objectives identify and clearly define the problem and list the objective(s) that the solution is intended to achieve
ii. Construction of an appropriate model; the model mimics the important elements of what is being simulated. A simulation model may be a physical or mathematical model, a mental conception, or a combination
iii. Experimentations with the model constructed; Once the simulation model is developed, the next step is to run it.
   - ✓ If the model is deterministic, with all its parameters known and constant, then only a single run would suffice.
   - ✓ On the other hand, if the simulation is stochastic in nature, with the parameters subject to random variation, then a number of runs would be needed to get a clear picture of the model performance.
   - ✓ The probabilistic simulation is akin to the random sampling where each run represents one observation. Thus, statistical theory can be used to determine the optimal sample size
iv. Evaluations of the results of simulations; The interpretation of results is, in a large measure, dependent on the extent to which the simulation model portrays the reality.

MONTE CARLO SIMULATION(Computer Simulation);

It can be described as a numerical technique that involves modelling a stochastic system with the objective of predicting the system's behavior. This method is used when the given process has a random, or chance, component.

In using the Monte Carlo method, a given problem is solved, by simulating the original data with random number generators.

Applications of Simulation;

- Police dispatching and beat design;
- Location of emergency vehicles like ambulances
- Making inventory policy decisions
- Evaluation of operating alternatives at airports;
- In financial planning—both portfolio selection and capital budgeting,
- Scheduling the production processes;
- Large scale military battles as well as individual weapons systems for aiding in the designing of both the weapon systems and of the strategic and tactical operations

Assignment;

An Assignment problem involves **assignment** or **matching** of two things, e. g. matching of workers and jobs or matching of salesmen and areas etc. The basic principle in Assignment problem is that the matching is on a **one to one** basis.

There are four Methods for solving an Assignment Problem;

a. Complete enumeration method;
b. Transportation Method
c. Simplex Method
d. Hungarian Assignment Method (HAM):

Transportation;

Transportation models are special types of linear programming models. It helps in establishment of one to many linking or relationships or routes for movement of goods or services from sources or origins or factories to the destinations or warehouses or customers or wholesalers or retailers or distribution channels with the minimum total transportation cost. This model is applicable not only for solving problems of transportation but also for solving a variety of industrial problems.

Term Degeneracy in a Transportation Problem; m+n-1 ≠ Allocated Cells;

Linear Programming;

Linear programming (**LP, or linear optimization**) is a mathematical method for determining a way to achieve the best outcome (such as maximum profit or lowest cost) in a given mathematical model for some list of requirements represented as linear relationships. Linear programming is a specific case of mathematical programming (mathematical optimization)

Main advantages of L.P. are as follows:

- ✓ Linear Programming helps in attaining the optimum use of productive factors.
- ✓ Linear programming techniques improve the quality of
- ✓ Highlighting of bottlenecks in the production processes is one of the most significant advantages of this technique. For example, when bottlenecks occur, some production factors (say machines) cannot meet demand while other remains idle for some of the time.
- ✓ Linear programming provides possible and practical solutions since there might be other constraints operating outside of the problem which must be taken into account.

Uses of Linear Programming technique;

The linear programming technique is useful in the following cases:

(i) It helps in determining optimum combination of several variables with given constraints and thus selecting the best possible strategy among various alternatives available.

(ii) Linear programming provides additional information for proper planning and control over various operations in the organisation.

(iii) The management must understand the activities of the organisation for constructing suitable mathematical model visualising the relationship between variables, if any, and making improvement over them. The linear programming helps in better understanding the phenomenon.

(iv) Linear programming contributes to the development of executives through the techniques of model building and their interpretations.

(v) Linear programming provides standards for the management problems by defining (a) the objectives to be pursued, (b) various restrictions to be imposed, (c) various alternatives available and relationship between them, (d) the contribution of each alternative to the objectives.

Application: The linear programming technique may be fruitfully applied in the following spheres:

(i) The linear programming can be used in production scheduling and inventory control so as to produce the maximum out of the resources available to satisfy the needs of the public by minimising the cost of production and the cost of inventory control.

(ii) The technique of linear programming can also be fruitfully used in solving the blending problems.

Where basic components are combined to produce a product that has certain set of specifications and one may calculate the best possible combination of these compounds which maximise the profits or minimise the costs.

(iii) Other important applications of linear programming can be in purchasing, routing, assignment and other problems having selection problems such as(a) selecting the location of plant, (b) deciding the transportation route within the organisation, (c) utilising the godowns and other distribution centres to the maximising, (d) preparing low-cost production schedules, (e) determining the most profitable product-mix, and (f) analysing the effects of changes in purchase prices and sale prices.

Network Analysis;

Network analysis is the general name given to certain specific techniques which can be used for planning, management and control of project. It often acts as a network management tool for breaking down projects into components or individual activities and recording the result on a flow chart or network diagram.

Applications:

1. Construction of a Residential complex,
2. Commercial complex,
3. Petro-chemical complex
4. Ship building
5. Satellite mission development
6. Installation of a pipe line project etc...

Differences between PERT & CPM

PERT	CPM
1. It is a technique for planning scheduling & controlling of projects whose activities are subject to uncertainty in the performance time. Hence it is a probabilistic model.	1. It is a technique for planning scheduling & controlling of projects whose activities not subjected to any uncertainty and the performance times are fixed. Hence it is a deterministic model.
2. It is an Event oriented system	2. It is an Activity oriented system
3. Basically does not differentiate critical and non-critical activities.	3. Differentiates clearly the critical activities from the other activities.
4. Used in projects where resources (men, materials, money) are always available when required.	4. Used in projects where overall costs is of primarily important. Therefore better utilized resources.
5. Suitable for Research and Development projects where times cannot be predicted.	5. Suitable for civil constructions.

2 Mark Questions for Practice;

1. **Discuss the objectives of Product Design.**

Answer;

The objectives of the Product Design are :

(i) The overall objective is profit generation in the long run
(ii) To achieve the desired product quality
(iii) To reduce the development time and cost to the minimum
(iv) To reduce the cost of the product
(v) To ensure producibility or manufacturability (design for manufacturing and assembly).

2. **Mentioning the generic components of innovation.**

Answer;

Four generic components of technological innovation are: basic research, applied research, development, and implementation.

(i) **Basic research** is research for the advancement of scientific knowledge that has no specific commercial uses. Basic research may, however, be in the field of present or potential interest to the company.
(ii) **Applied research** is research for the advancement of scientific knowledge that has specific potential commercial uses.
(iii) **Development** is technical activity concerned with translating basic or applied research results into products or processes.
(iv) **Implementation** is activity concerned with designing and building pilot models, equipment, and facilities, and initiating the marketing channels for products or services emerging from research and development.

3. **Define the Process Strategy.**

Answer;

A **process strategy** is an organization's approach to process selection for the purpose of transforming resource inputs into goods and services (outputs). The objective of a process strategy is to find a way to produce goods and services that meet customer requirement and product specification (i.e., design specifications) within the constraints of cost and other managerial limitations.

Key aspects in process strategy include:
(i) Make or buy decisions
(ii) Capital intensity and
(iii) Process flexibility

4. **Discuss the advantages of Vertical Integration.**

Answer;

Advantages of vertical integration are:

(i) Can sometimes increase market share and allow the firm enter foreign markets more easily.
(ii) Can achieve savings in production cost and produce higher quality goods.
(iii) Can achieve more timely delivery.
(iv) Better utilization of all types of resources.

5. **Discuss the techniques of Work Measurement.**

Answer;

The main techniques used to measure work are:

1. Direct Time Study.
2. Synthesis Method.
3. Analytical Estimating.
4. Pre determined Motion Time System (PMTS).
5. Work sampling or Activity Sampling or Ratio Delay Method.

6. **Define the Mean Absolute Deviation (MAD).**

Answer;

MAD is the ratio of sum of absolute deviations for all periods to the total number of periods studied. It is represented as below:

$$MAD = \frac{\text{Sum of absolute values of deviations for all periods}}{\text{Total number of periods studied}}$$

$$= \frac{\sum_{i=1}^{n} |\text{ForecastedDemand} - \text{Actual demand}|_i}{n}$$

7. What are the factors affecting the process planning?

Answer;

Factors affecting process planning

a. Volume (quantity) of production.
b. Delivery dates for components or products.
c. Accuracy and process capability of machines.
d. The skill and expertise of manpower.
e. Material specifications.
f. Accuracy requirements of components or parts.

8. Mentioning the different types of Layout.

Answer;

The different types of layout are:

a. Process layout;
b. Product layout;
c. Fixed position layout;
d. Cellular Manufacturing (CM) layout;
e. A combination of the above.

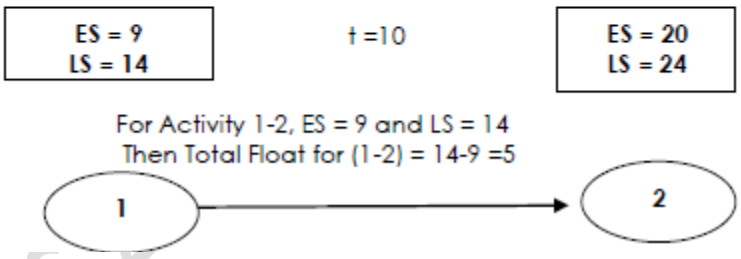
9. Discuss about the Total Float.

Answer;

Total Float

Amount of time by which the completion of an activity could be delayed beyond the earliest completion time without affecting the overall project duration time. It is measured by the maximum time of the difference between maximum time available to perform activity and activity duration time or the difference between latest start time and earliest start time.

$$TS(a) = LS(a) - ES(a)$$



10. Define Quality Function and Development (QFD)

"QFD is a systematic and organized approach of taking customer needs and demands into consideration when designing new product and services or when improving existing products and services." Another name for this approach is "customer-driven engineering" because the voice of the customer is diffused throughout the product (or service) development life cycle.

11. What is Capacity Planning?

Answer;

Capacity Planning is the process of determining the production capacity needed by an organization to meet changing demands for its products. In this context, "capacity" is the maximum amount of work that an organization is capable of completing in a given period.

12. **What is Quality Circle**?

Answer;

Quality Circle: is a small group of 6 to 12 employees doing similar work and who voluntarily meet together on a regular basis to identify improvements in their respective work areas.

13. **State the factors affecting Process Planning.**

Answer;

Following are the factors affecting Process Planning:

(i) Volume of production;
(ii) Delivery dates for components of products;
(iii) Accuracy and process capability of machines;
(iv) Skill and expertise of manpower;
(v) Material specifications;
(vi) Accuracy requirements of components or parts.

14. **State the purpose of preparing Assembly Charts.**

Answer;

Assembly Charts are prepared to provide an overall macro view of how materials and sub-assemblies are assembled to form finished products. These charts list all major materials, components, sub-assembly operations, inspections and assembly operations.

15. **List the limitations of using Bar Chart.**

Answer;

Following are the limitations of using Bar Chart:

(i) Bar chart becomes too cumbersome while dealing with big and complex projects when considered in detail and efforts were to find out interaction/interdependence.
(ii) Bar chart does not indicate which tasks should be given priorities as regards the resources, i.e., men, money, materials, machinery, etc.
(iii) Changes in schedule cannot be evaluated.
(iv) It does not tell tolerance in activity times.
(v) It does not show continuing interrelationships of activities.
(vi) Bar chart it is not clear which are the activities dependant on each other and which are independent.

16. **List the success factors associated with Quality Functions Deployment (QFD)?**

Answer;

Success Factors associated with Quality Function Development (QFD) are:

(i) Accurate Customer Voice.
(ii) Strong Management Commitment.
(iii) A good consultant.
(iv) Regular projects reviews.
(v) Milestone celebration to keep interest high and to develop a sense of closure.
(vi) Sharing with other teams to facilitate deeper learning.

17. **What is Linear Programming?**

Answer;

Linear Programming is an optimization technique that allows the user to find a maximum profit/revenue or a minimum cost, based on the availability of limited resources and certain constraints.

18. **Define Standardisation.**

Answer;

Standardisation refers to design activity that reduces variety among a group of products or parts. This will result in higher volume for each product or part model which can lead to lower production costs, higher product quality and lower inventory and higher ease of automation.

19. **Who is a Qualified Worker?**

Answer;

A qualified worker is one who is accepted as having the necessary physical attributes, possessing the required intelligence and education and having acquired the necessary skill and knowledge to carry out the work in hand to satisfactory standards of safety, quantity and quality.

20. Define P-D-C-A Cycle.

Answer;

P - Plan (process) the improvement
D - Do implement the plan
C- Check- check hoe closely result meets goals
A- Act- use the improved process as standard practice

21. What is Capacity Planning?

Answer;

Capacity Planning is the process of determining the production capacity needed by an organization to meet changing demands for its products. In this context, —capacity‖ is the maximum amount of work that an organization is capable of completing in a given period.

22. Designing for Quality

Answer;

Building product quality into the product design is the first step in producing products of superior quality. This is known as **—quality of design‖** which is followed by **—quality of conformance.‖** Quality of design refers to the quality specifications incorporated in the design. It consists of quality characteristics such as appearance, life, safety, maintenance and other features of the product. Quality of conformance is the degree to which the product actually conforms to the design specification. Designing products for quality consists of three aspects of design— (a) robust design, (b) design for production and (c) design for reliability.

23. Types of processes

Answer;

Types of Processes: Basically, processes can be categorised as:

i. Conversion processes, i.e., converting the raw materials into finished products (for example, converting iron ore into iron and then to steel). The conversion processes could be metallurgical or chemical or manufacturing or construction processes.
ii. Manufacturing processes can be categorised into (a) Forming processes, (b) Machining processes and (c) Assembly processes.
iii. Testing processes which involve inspection and testing of products (sometimes considered as part of the manufacturing processes).

a. **Forming processes** include foundry processes (to produce castings) and other processes such as forging, stamping, embossing and spinning. These processes change the shape of the raw material (a metal) into the shape of the workpiece without removing or adding material.

b. **Machining processes** comprise metal removal operations such as turning, milling, drilling, grinding, shaping, planning, boring etc.

c. **Assembly processes** involve joining of parts or components to produce assemblies having specific functions. Examples of assembly processes are welding, brazing, soldering, riveting, fastening with bolts and nuts and joining using adhesives.

24. Capital intensity;

Answer;

Capital intensity is the mix of equipment and human skills in a production process. Capital intensity will be high if the relative cost of equipment is high when compared to the cost of human labour. **Capital intensity** means the predominant resource used in manufacturing, i.e., capital equipments and machines rather than labour. Decision regarding the amount of capital investment needed for equipments and machines is important for the design of a new process or the redesign of an existing one. As the capabilities of technology increase (for example automation), costs also will increase and managers have to decide about the extent of automation needed. While one advantage of adding capital intensity is significant increase in product quality and productivity, one big disadvantage can be high investment cost for low-volume operations.

25. Principles of Total Quality

Answer;

- Focus on the customer (Both internal & external)
- Participation and team work
- Employee involvement and empowerment
- Continuous improvement and learning.

26. Mentioning the Five principles of TQM.

The Five Principle of Total Quality Management:

(i) Concentrate on the customer
(ii) Do it right first time
(iii) Communication and educate
(iv) Measure and record
(v) Do it together

27. Principles of Total Quality Control (TQC)

- Top management policies- Zero defects, continuous improvement etc.
- Quality control training for everyone
- Quality at product/service design stage
- Quality materials from suppliers
- Quality control in production
- Quality control in distribution, installation and usage.

28. Predictive Maintenance

Answer;

Predictive Maintenance: One of the newer types of maintenance that may be anticipated to gain increasing attention is called predictive maintenance. In this, sensitive instruments (e.g., vibration analysers, amplitude meters, audio gauges, optical tooling, pressure, temperature and resistance gauges) are used to predict trouble. Conditions can be measured periodically or on a continuous basis and this enables the maintenance people to plan for overhaul. This will allow an extension to the service life without fear of failure.

29. Diffusion

Answer;

Diffusion: Diffusion is relevant to both process and product change. Process diffusion takes place when the overtime use of the process is diffused to other firms. Product diffusion refers primarily to the widespread use of the product among consumers rather than among firms. The rate of diffusion depends upon several factors and has many implications, particularly with respect to patents and monopoly.

30. Approach of Six Sigma

Answer;

Six Sigma is a very rigorous approach to improving quality within products and services. Processes that are critical to products and services must be analyzed in detail. Generally, Six Sigma will follow a four phase approach:

1. **Measure –** Determine the error or defect rate
2. **Analyze –** Understand the process

3. **Improve –** Reach for a higher Sigma
4. **Control –** Monitor through measurement

31. Describe about capital spare parts.

Answer;

Regular spares and Insurance spares are two ends of the spectrum; Capital spares fall somewhere in between. These spares are expensive and therefore it would be desirable to keep only as many as would be required from the viewpoint of service level. This decision is guided by the probability that a certain number of them are required over the life of the equipment.

32. Limitations of Preventive Maintenance.

Answer;

i. More expensive in the short term and during the initial stages of introduction of preventive maintenance programme.

ii. Inspection of plant, equipment and machinery will have to be carefully planned and implemented and improved over a period of time.

33. What are the success factors of QFD?

(i) Accurate Customer Voice.
(ii) Strong Management Commitment.
(iii) A good consultant.
(iv) Regular projects reviews.
(v) Milestone celebration to keep interest high and to develop a sense of closure.
(vi) Sharing with other teams to facilitate deeper learning.

34. Mention the characteristics of Just –in- Time systems.

Answer;

JIT systems focus on reducing inefficiency and unproductive time in the production process to improve continuously the process and quality of the product or service. Employee involvement and inventory reductions are essential to JIT operations. The salient characteristics of JIT are:

(i) Pull method of material flow
(ii) Constantly high quality
(iii) Small lot sizes
(iv) Uniform workstation loads
(v) Standardized components and work methods
(vi) Close supplier ties
(vii) Flexible workforce
(viii) Line flow strategy
(ix) Automated production and
(x) Preventive maintenance.

35. List the name of the Qualitative Approaches regarding the Forecasting Technique.

Answer;

- Grass – Root Forecasting
- Focused Forecasting
- Historical Analogy
- Panel Consensus
- Delphi Method

36. Discuss the Input/ Output Control.

Answer;

It is a control technique where the planned and actual inputs are monitored. Actual input is compared to planned inputs to identify where work center output might vary from the plan because work is not available at the work center. Actual output is also compared to the planned output to identify problems within the work center. Planned and actual inputs as well as outputs have an impact on the Work-in-Process (WIP) inventory.

37. Where did QFD come from? (PTP June 14)

Yoji Akao of Tamagawa University is the key contributor to QFD Development in Japan. There are 30 matrices in his approach. The QFD team can pick and choose the matrix which would be of most use for a particular phase of product development.

Another expert in the area of QFD is Fukahara. He is associated with the Central Japan Quality Control Association. He mainly focuses on the house of quality, namely the product definition aspect. There is also the four phase (or four matrices) approach promoted by the American Supplier Institute (ASI). There are,of course, many other approaches of QFD.

38. **Name five general purpose machines.**

Answer ;

(i) Lathe
(ii) Drilling machine
(iii) Grinding machine
(iv) Milling machine
(v) Planning machine

39. **List the uses of Jigs and Fixtures.**

Answer;

i) Jigs quickly and accurately guide the tools .Difficult operations are rendered easier, speedier, and yet more accurate by using jigs.
ii) Jigs help in mass production by producing accurately machined interchangeable parts.
iii) Fixtures are essential in all machine work, because work must be firmly held at the time of working of tools.
iv) Fixtures used along with jigs increase the speed and accuracy of work.

40. **Write a short note on Value Engineering.**

Answer;

Value engineering or value analysis is concerned with the improvement of design and specifications at various stages such as research, development, design and product development. Value engineering aims at cost reduction at equivalent performance. It can reduce costs to the extent of 15% to 70% without reducing quality. While value engineering focuses on preproduction design improvement, value analysis, a related technique seeks improvements during the production process.

41. **Design for Manufacturing and Design for Assembly are related concepts in manufacturing'. Justify.**

Answers;

Design for Manufacturing (DFM) and **Design for Assembly (DFA)** are related concepts in manufacturing. The term design for manufacturing is used to indicate the designing of products that are compatible with an organisation's capability. Design for assembly focuses on reducing the number of parts in a product or on assembly methods and sequence that will be employed.

42. **Define Time Study.**

Answers;

A technique of work-measurement used for determining as accurately as possible from a limited number of observations, the time necessary to carry out a given activity at a denned standard of performance. A stop watch is used for the purpose of recording the actual time taken by the worker under observation to perform various elements of the work or task.

43. **Define Customer-Driven Quality.**

Answer;

Customer-Driven Quality: Quality is meeting or exceeding customer expectations. The term —customer‖ includes both the —internal customer‖ and the —external customer‖ in the —customer chain‖.

44. **What is Rotable Spare?**

Answer;

These are repairable and re-usable spares, such as a jet engine or an electric motor which can be reconditioned after failure and put back in operation.

45. **Define Material Planning.**

Answer;

Materials planning is the scientific way of determining the requirements of raw materials, components, spares and other items that go into meeting the production needs within economic investment policies. Materials planning is a subset of the overall production planning and control system which has a broad perspective.

46. **Define Repetitive focus.**

Answer;

A repetitive process is a product oriented production process that uses modules.
It falls between product focus and process focus. It uses modules which are parts or components prepared often in a continuous or mass production process. A good example of repetitive process is the **assembly line** which is used for assembling automobiles and household appliances and is less flexible than process-focused facility.

47. **Explain the term _worker-machine chart.'**

Answer;

The man machine chart or worker-machine chart: This is a variation of multiple activity chart and illustrates the operation and delays of the operator and the machine which he operates. An example of man machine chart may be one worker running two machines simultaneously.

48. **A project starts with statement of work.'- Justify.**

Answer;

Project planning deals with specified tasks, operations or activities, which must be performed to achieve project goals. A project starts with **statement of work**. It may be a written description of objectives (rules/regulations/ constraints/restriction) to be achieved with a brief statement of work to be done and a proposed schedule specifying the start and completion dates of the project.

49. **Define Maintenance Engineering.**

Answer;

Maintenance Engineering is that function of production management that is concerned with the day-to-day problems of keeping the physical plant in good operating condition.

50. **Explain Total Productivity.**

Answer;

Total Productivity:
Here, productivity is calculated with respect to the total cost or the total finances committed, instead of one input, as given below:

$$\text{Productivity} = \frac{\text{Value added}}{\text{Total factor cost}} = \frac{\text{Value of gross output}}{\text{Total value of inputs.}}$$

The total factor productivity (TFP) is a measure of the overall changes in production efficiency.

51. **State the three levels of quality.**

Answer;

Three levels of quality

1	Organisation level	Meeting external customer requirements
2	Process level	Meeting the needs of internal customers
3	Performer level (Job level or task design level	Meeting the requirements of accuracy, completeness innovation, timeliness and cost.

52. **Describe Pragmatic JIT.**

Answer;

Pragmatic JIT consist of a set of techniques, some fairly technical, that relate to machine change-overs, lay-out design, product simplification, quality training, equipment maintenance and so on.

53. **List the disadvantages of Vertical Integration.**

Answer;

Disadvantages of vertical integration are:

- Not attractive for low volumes.
- High capital investment and operating costs.
- Less ability to react more quickly to changes in customer demands, competitive actions and new techniques.

54. **State the meaning of Concurrent Engineering.**

Answer;

Concurrent engineering means bringing design and manufacturing people together early in the design phase to simultaneously develop the product and processes for manufacturing the product. Recently this concept has been enlarged to include manufacturing personnel, design personnel, marketing and purchasing personnel in loosely integrated cross-functional teams. In addition, the views of suppliers and customers are also sought frequently. This

will result in product designs that will reflect customer wants as well as manufacturing capabilities in the design stage itself.

55. Explain the term Route Sheet.

Answer;

A route sheet is a document providing information and instructions for converting the raw materials into finished parts or products. It defines each step of the production operation and lays down the precise path or route through which the product will flow during the conversion process.

56. List the three axioms of Deming's Triangle.

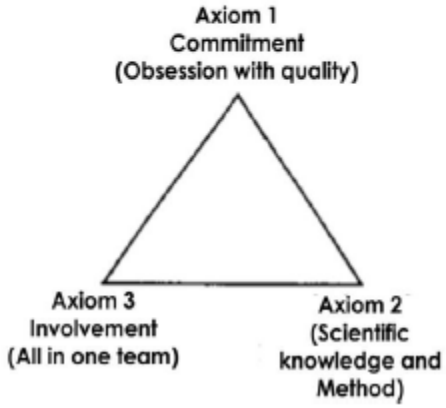
Answer;

Deming's Triangle (3 axioms):

Axiom 1 : Commitment (Obsession with quality)

Axiom 2 : (Scientific Knowledge & Method)

Axiom 3 : Involvement (All in one team)



57. State the three prominent kinds of failure probability distribution.

Answer;

The phenomenon of breakdown or failure is very important in Maintenance Management. A vital information in this regard relates to Failure Statistics. An important statistic is the relative frequency of failure or probability density of failure with respect to the age of the item in question. It has been observed that there are three prominent kinds of failure probability distribution:

a. Normal Distribution
b. Negative exponential Distribution
c. Hyper-exponential Distribution

58. Define the term Rescue maintenance

Answer;

Rescue maintenance refers to previously undetected malfunctions or such sudden changes that were not anticipated but require immediate solution. Rescue maintenance is unplanned. Thus a system that is properly developed and tested should have few occasions of rescue maintenance.

59. State the need for Ergonomics.

Answer;

Poorly designed products may cause work-related accidents resulting in injuries to users. Hence, comfort, safety and ease of use for the users are becoming more important quality dimensions that have to be considered in product design. Human Factor Engineering or Ergonomics applies knowledge of human capabilities and limitations to the design of products and processes.

60. List the three Principles of Motion Economy.

Answer;

The rules of motion economy and efficiency which referred to hand motions of operators were developed by Gilbreth. The principles of motion economy are divided into three groups, viz.,

i. Effective use of the operator

ii. Arrangement of the workplace
iii. Tools and equipment

61. List the different Quality Circle techniques.

Answer;

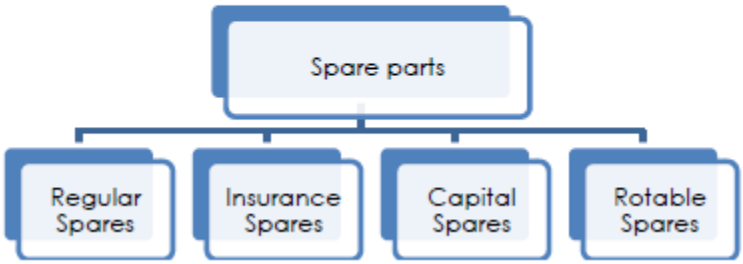
It is necessary for QC to adopt following technique in order to smooth working of QC.

(i) Team is necessary for QC to adopt following technique in order to smooth working of QC.
(ii) Pareto Principle
(iii) Collection of Data
(iv) Analysis of Problem
(v) Problem Selection and Solution
(vi) Presentation to Management
(vii) Code of Conduct.

62. Discuss about Spare Parts.

Answer;

Spare parts constitute significant portion of inventory investment and therefore, their planning and control are important. Spare parts are required for maintenance: preventive and breakdown.



63. Describe Process Selection.

Answer;

Process selection refers to the way production of goods or services is organised. It is the basis for decisions regarding capacity planning, facilities (or plant) layout, equipments and design of work systems. Process selection is necessary when a firm takes up production of new products or services to be offered to the customers.

64. Write a note on Line Balancing.

Answer;

Line balancing is arranging a production line so that there is an even flow of production from one work station to the next, i.e. there are no delays at any work station that will leave the next work station with idle time.
Line balancing is also defined as —the apportionment of sequential work activities into work stations in order to gain a high utilization of labour and equipment and therefore minimize idle time.‖

65. List the ten dimensions of service quality.

Answer;

Ten dimensions of service quality are - 1. Reliability 2. Responsiveness 3. Competence 4. Access 5. Courtesy 6. Communication 7. Credibility 8. Understanding 9. Security/Safety 10. Tangibles.

66. Explain the term Rotable Spares.

Answer;

Rotable spares are repairable and re-usable spares, such as a jet engine or an electric motor which can be reconditioned after failure and put back in operation. This situation can be visualised in a Multiple Channel Single Service Queuing theory format, where the defective equipments are the arrivals and the spares are the servers. The service times are given by the distribution of time to recondition a spare. The inter-arrival times of the defective items can also be modelled in terms of a probability distribution.

67. Discuss the Input/ Output Control.

Answer;

It is a control technique where the planned and actual inputs are monitored. Actual input is compared to planned inputs to identify where work center output might vary from the plan because work is not available at the work center. Actual output is also compared to the planned output to identify problems within the work center. Planned and actual inputs as well as outputs have an impact on the Work-in-Process (WIP) inventory.

68. State the applications of Programme Evaluation and Review Technique (PERT)

Answer;

PERT is useful in the following situations:

- The project should have identifiable activities.
- The activities should have clear starting and ending points.
- Project is complicated and consists of many inter-related tasks.
- Technique is good for projects, where alternative options, sequence of activities and time period are involved.

69. What is Process Flexibility?

Answer;

Process flexibility refers to the degree to which the system can be adjusted to changes in processing requirements due to such factors as changes in product or service design, changes in volume of products produced and changes in technology.

70. What are the two directions of vertical integration?

Answer;

Two directions of vertical integration are:

(i) Backward integration which represents moving upstream towards the sources of raw materials and parts, for example a steel plant mill going for backward integration by owning iron ore and coal mines and a large fleet of transport vehicles to move these raw materials to the steel plant.

(ii) Forward integration in which the firm acquires the channel of distribution (such as having its own warehouses and retail outlets).

71. What are the salient points of the Activity-On –Node convention?

Answer;

Salient points of the Activity-On Node convention are:

- Each activity is represented by a node in the network.
- A precedence relationship between two activities is represented by an arc or link between the two.
- Node is represented by a circle and indicates an Event, a point of time where one or more activities start and/or finish.

72. What is Predictive Maintenance?

Answer;

One of the newer types of maintenance that may be anticipated to gain increasing attention is called predictive maintenance. In this, sensitive instruments (e.g. vibration analysers, amplitude meters, audio gauge, optical tooling, pressure, temperature and resistance gauges) are used to predict trouble. Conditions can be measured periodically or on a continuous basis and this enables the maintenance people to plan for overhaul. This will allow an extension to the service life without fear of failure.

73. Explain the term Pacing.

Answer;

Pacing refers to the fixed timing of the movement of items through the process. In a serial process, the movement of items through each activity (or stage) is often paced in some mechanical way in order to to coordinate the line.

74. Define Order control.

Answer;

The most, common type of production control is called order control. This type of control is commonly employed in companies with intermittent production systems, the so-called job-lot shops. Under this method, orders come into the shop for different quantities for different products. Therefore, production planning and control must be based on the individual orders.

75. Define Forecast Error.

Forecast error is the numeric difference between the forecasted and actual demand. It is desirable that the difference between forecasted and actual demand is low as possible. There are two measures of error – (i) Mean Absolute Deviation (MAD) and (ii) Bias.

76. Define the term „Specification.“

Answer;

A Specification is a detailed description of a material, part or product, including physical measures such as dimensions, volume, weight etc. These physical measure are given tolerances (acceptable variations). Tolerances are stated minimum and maximum for each dimension of a product. Tight tolerances facilitate interchangeability of parts and allows ease of assembly and effective functioning of the finished products.

77. What is Operation Process Chart?

The basic process chart, called an operation process chart, is understood as a graphic representation of the points at which the materials are introduced into the process and the sequence of inspections and all operations except those involved in materials handling. It includes information considered desirable for analysis such as time required to carry out the operation and the location.

78. Define Partial Productivity.

Partial Productivity: This measures productivity of one factor or input, keeping other factors or inputs constant or unchanged. Mathematically, this is a partial derivative of the output with respect to one input, keeping the other inputs constant.

79. What do you mean by the term Reliability Improvement?

If an equipment system has a reliability which needs further improvement, how should the reliabilities of the various components be increased in order to get the desired improvement in the reliability of the equipment system.

80. Define Quality Control.

Answer;

Quality Control may be defined as “a system that is used to maintain a desired level of quality in a product or service”. It is a systematic control of various factors that affect the quality of the product. Quality Control can also be defined as that “Industrial Management technique by means of which product of uniform acceptable quality is manufactured”.

81. Explain Utilization.

Answer;

Utilization = Actual Hours/Scheduled available hours Utilization factor and efficiency are both assumed to develop realistic and feasible plans. Utilization is the percentage of a resource’s maximum capacity, which is expected to involve in production. For example, it is not expected by an employee to work effectively for every minute in an 8 hour shift. All workers including devoted employees need breaks to attend to their personal needs.

82. Explain the term Operations Design.

Answer;

Operations Design is concerned with the design of the individual manufacturing operation. It examines the man-machine relationship in the manufacturing process. Operations design must specify how much labour and machine time is required to produce each unit of the product.

83. Explain the term Aggregate Planning.

Answer;

The term aggregate planning is often employed in the capacity context. The implication is that such planning is concerned with total demand, i.e. all demands collected together. This is of relevance in operating systems where different goods or services are provided. In such cases capacity planning will seek to estimate or measure all demands and express the total in such a way as to enable enough of all resources (or total capacity) to be provided. Demand for all outputs must therefore be expressed in common capacity-related units such as the number of resources or resource hours required.

84. State the meaning of Technology Fusion.

Answer;

Technology fusion refers to the process of combining several current technologies and scientific knowledge to create a hybrid technology. Adding one technology to another, results in synergic effects. For example in machine tool industry NC, CNC machines are the result of fusion of electronics and mechanical technologies.

85. **State the meaning of Facility Loading.**
Answer;
Facility loading means loading of facility or work centre and deciding which jobs to be assigned to which work centre or machine. Loading is the process of converting operation schedules into practice.
86. **State the three fundamental concepts of JIT.**
Answer;
i. Elimination of waste and variability
ii. —Pull‖ versus —Push‖ system and
iii. Manufacturing cycle time (or —throughput‖ time).

87. **'Six Sigma provides flexibility in the new millennium of 3C's' – List them.**
a. Change: Changing society
b. Customer: Power is shifted to customer and customer demand is high
c. Competition: Competition in quality and productivity.
88. **Define Total Productivity.**
Total Productivity:
Here, productivity is calculated with respect to the total cost or the total finances committed, instead of one input, as given below:

$$\text{Productivity} = \frac{\text{Value added}}{\text{Total factor cost}} = \frac{\text{Value of gross output}}{\text{Total value of inputs.}}$$

The total factor productivity (TFP) is a measure of the overall changes in production efficiency.
89. **Explain Flow Process Chart.**
Flow process charts are graphic representations of the sequence of all operations, transportation, inspections, delays and storages occurring during a process or a procedure and include information considered desirable for analysis such as time required and distance moved.
The flow process chart could be of three types, viz., (i) Flow process chart material or product type. (ii) Flow process chart-man type. (iii) Flow process chart machine type or equipment type.
90. **Explain Delayed Differentiation.**
Answer;
Delayed Differentiation is the process of producing but not quite completing, a product, postponing completion until customer preferences or specifications are known. Modular design is a form of standardisation in which component parts are grouped into modules that are easily replaced or interchanged to produce varieties of the same basic product. One example is a computer system in which a customer can choose a particular configuration depending on the computing, capability desired by the customer. Modular design helps mass customisation.
91. **Distinguish between Regular Spares and Insurance Spares.**
Answer ;
Regular Spares are required regularly and so, in substantial numbers. Insurance Spares have a very high reliability and are required rarely.
92. **Write the formula for Input Efficiency and Effectiveness.**
Answer;

$$\text{Input Efficiency} = \frac{\text{Actual Consumption}}{\text{Desired or standard consumption}}$$

$$\text{Effectiveness} = \frac{\text{Target Achieved}}{\text{Target Achievable}}$$

93. **List the various steps in New Product Development.**
Answer;
The steps in New Product Development are: (i) Exploration, (ii) Screening, (iii) Business Analysis, (iv) Development, (v) Testing, and (vi) Commercialisation.
94. What is processing time?
Answer;

The time needed to produce goods or provide services. This can involve scheduling repairing equipment, methods used, inventories, quality, training and the like.

95. What are the main functions of production planning?

Answer;

The main functions of production planning are: (i) Estimating, (ii) Routing, (iii) Scheduling, and (iv) Loading.

96. What is measured by regression analysis?

Answer;

Regression analysis identifies the movement of two or more interrelated series. It is used to measure the changes in a variable (dependent variable) as a result of changes in Other variables (independent variables).

97. What is meant by „Total‟ in Total Productive Maintenance?

Total in —Total Production Maintenance‖ means: (i) Total employee involvement, (ii) Total equipment effectiveness (i.e., Zero breakdown) and (iii) Total maintenance delivery system.

98. Write Pareto principle?

Answer;

Italian Sociologist Pareto‟s principle is found useful in „QC‟ at every level, Pareto proved after studying the economic condition of Italy that 80% of the country‟s wealth is divided between 20% of the people. This is also known as 80 – 20 principle. According to this principle if 80% of accidents are according in 20% of factory then 20% factories are having unsafe working procedures. According to Pareto, the important cause are always quite less in number „QC‟ focuses its attention on these less but important problems.

99. List the major phases in production planning and control function.

Answer;

The major phases in production planning and control function: (1) Planning Phase, (2) Action Phase, and (3) Control Phase.

100. In what way does the objective of „value engineering‟ differ from that of „Value analysis‟?

Answer;

Value engineering aims at cost reduction at equivalent performance. It can reduce costs to the extent of 15% to 70% without reducing quality. While value engineering focuses on preproduction design improvement, value analysis, a related technique, seeks improvements during the production process.

101. What is „Bill of Materials‟?

Bill of materials is nothing but a document which shows for a given product or sub-unit, the list of materials required, unit consumption, and location code (for storage). The condition of supply such as “bought-out” or “made in-house” will also be indicated.

102. What are the different approaches to overcome hurdles in the management of productivity improvements?

Answer;

Different approaches to overcome hurdles in the management of productivity improvements are: (i) Management by internal motivation (i.e., KAIZEN). (ii) Management by incentives. (iii) Management by fear.

103. ‘The principles of motion economy are divided into three groups.’ List the groups.

Answer;

The principles of motion economy are divided into three groups, viz.,

(1) Effective use of the operator

(2) Arrangement of the workplace

(3) Tools and equipment

104. Define Contingency Allowance in Time Study.

Answer;

Contingency Allowance (CA) in Time Study is given for infrequent or non-repetitive activities such as obtaining special materials from stores, sharpening of tools, getting a special tool from the tool stores, and consultation with the supervisor. It is usually about 5% of normal or basic time.

105. What are the twin objectives of operations Management?

Answer;

1. Customer Satisfaction:
2. Optimal Utilization of resource:

106. Define Efficiency?

Answer;

Efficiency is ratio of the actual output of a process relative to some standard efficiency is used to measure the loss or gain in a process.

107. What is Monte Carlo Simulation?

Answer;

Monte Carlo method is also called computer simulation, it can described as a numerical technique that involves modeling a stochastic system with the objective of predicting the system‟s behavior. The chance element is a very significant feature of Monte Carlo simulation and this approach can be used when the given process has a random, or chance, component. In using the Monte Carlo method, a given problem is solved, by simulating the original data with random number generators.

2 Mark Problem Questions for Practice;

1. The demand function of a firm is q = 200 – 10 p and the average cost function is $AC = 10 + \frac{q}{25}$. If the firm's objective is to maximize profit, what will be its profit maximizing output?

2. A workshop operates on 2 shifts of 8 hours per day. It has 10 machines. It works for 5 days in a week. Machine utilization is 90% and the efficiency of the machines is 85%. Calcutta the designed/ rated capacity of the workshop in standard hours.

3. A production manager of a plant must determine the lot size for a particular component that has a steady demand of 50 units per day. The production rate is 200 units per day, Annual demand is 10,000 units, set-up cost is ₹ 200, annual holding cost is rupee 0.20 per unit and the plant operates 350 days per year. Determine the economic production lot size.

4. If a firm sells 16,000 units, its loss is ₹ 40,000. But if it sells 20,000 units, its profit is ₹ 40,000. Calculate Fixed Cost.

5. Monthly demand for a component 4,000 units. Setting –up cost per batch ₹ 120. Cost of manufacture per unit ₹ 20. Rate of interest 10% P.a. Calculate the EBQ.

6. The time study of a machinery operation recorded cycle time of 8.0, 7.0 ,8.0, 9.0 and 8.0 minutes. The analyst rated the observed worker as 90%. The firm uses a 0.15 allowance fraction. Compute the standard time.

7. The demand for three months for 100 watt bulbs is given below:

Period	January	February	March
Demand	1,000	1,200	1,600

If the weight assigned to the period of January, February and March are 0.25,0.35 and 0.4 respectively, forecast the demand for the month of April by using Weighted Moving Average Method.

8. A company intends to buy a machine having a capacity to produce 3,40,000 good parts per annum. The machine constitutes a part of the total product line. The system efficiency of the product line is 85%.The machine works for 2,000 hours/year.
Find the system capacity.

9. The demand for sewing machine was estimated as 1000 per month for 5 months. Later on the actual demand was found as 900, 1050, 1000, 1100 and 950 respectively. Workout Bias.

10. Monthly demand for a component 8,000 units. Setting –up cost per batch ₹ 120. Cost of manufacture per unit ₹ 40. Rate of interest 10% P.a. Calculate the EBQ.

11. The main shaft of an equipment has a very high reliability of 0.980.The equipment comes from Japan and has a very high downtime cost associated with the failure of this shaft. This is estimated at ₹2 crores as the cost of sales lost and other relevant costs. However, this spare is quoted at ₹10 lakh at present. Should the shaft spare be procured along with the equipment and kept or not?

12.

If a firm sells 16,000 units, its loss is ₹ 40,000. But if it sells 20,000 units, its profit is ₹ 40,000. Calculate Fixed Cost.

13.

An 8 hours work measurement study in a plant reveals the following: Units produced = 320 nos. Idle time = 15%. Performance rating = 120%. Allowances = 12% of normal time. Determine the standard time per unit produced.

14. PTP June

A workshop operates on 2 shifts of 8 hours per day. It has 10 machines. It works for 5 days in a week. Machine utilization is 90% and the efficiency of the machines is 85%. Calculate the designed/rated capacity of the workshop in standard hours.

15.

A departmental store has one cashier. During the rush hours, customers arrive at a rate of 20 customers per hour. The average number of customers that can be handled by the cashier is 24 per hour. Assume the conditions for use of the single – channel queuing model. Find out average time a customer spends in the system.

16.

A firm operates 6 days a week on single shift of 8 hours per day basis. There are 10 machines of the same capacity in the firm. If the machines are utilized for 75 percent of the time at a system efficiency of 80 percent, what is the rated output in terms of standard hours per week?

17.

An analyst wants to obtain a cycle time estimate that is within ± 5% of the true value. A preliminary run of 20 cycles took 40 minutes to complete and had a calculated standard deviation of 0.3 minutes. What is the coefficient of variation to be used for computing the sample size for the forthcoming time study?

18.

Standard time for a task is 8 hours. Calculate the efficiency of a workman in the following cases:
(i) Worker completes the job in 10 hours.
(ii) Worker completes the job in 6 hours.

19.

The demand for sewing machine was estimated as 1000 per month for 5 months. Later on the actual demand was found as 900, 1050, 1100 and 950, respectively. Calculate the Tracking Signal.

20.

An assembly line of an item A has the following output in a 10 week period:

Week No	1	2	3	4	5	6	7	8	9	10
Std. hrs produced	350	375	380	400	300	325	340	370	390	350

Calculate the demonstrated capacity of the assembly line per week.

21.

A firm operates 6 days a week on single shift of 8 hours per day basis. There are 10 machines of the same capacity in the firm. If the machines are utilized for 75 percent of the time at a system efficiency of 80 percent, what is the rated output in terms of standard hours per week? [2]

22.

A worker works for 8 hours in each shift, but during that time he had clocked for 7 hours on the job. Calculate his utilization. [2]

23. Solve the game with the following pay- off matrix. [2]

		B_1	B_2	B_3	B_4
Player A	A_1	1	7	3	4
	A_2	5	6	4	5
	A_3	7	2	0	3

24. For a certain element of work, the basic time is established to be 20 seconds. A time study observer record rating of 125 on a 100 normal scale. What is the observed time?

25. Compute the productivity per machine hour with the following data.

Month	No. of machines employed	Working Hours	Machine hours	Production Unit
March	400	225	90,000	99,000

26. A worker is employed for 12 hours. During this period he takes 8 hours to complete a job with the standard time of 7 hours. Calculate the productivity of the workers as a percentage.

27. A steel plant has a designed capacity of 50,000 tons of steel per day, effective capacity of 40,000 tons of steel per day and an actual output of 36,000 tons of steel per day. Compute the efficiency of the plant and its utilisation.

28. An analyst wants to obtain a cycle time estimate that is within ± 5% of the true value. A preliminary run of 10 cycles took 50 minutes to complete and had a calculated standard deviation of 0.4 minutes. What is the coefficient of variation to be used for computing the sample size for the forthcoming time study?

29. Shin's Car Wash & Dry is an automatic, five-minute operation with a single bay. On a typical Saturday morning, cars arrive at a mean rate of ten per hour, with arrivals tending to follow a poison distribution. Find the average number of cars in line.

30. The demand for 100 Watt bulbs in the past 5 months is given as below:

Month	Demand
April	700
May	700
June	800
July	600
August	500

Calculate the moving average for a period of 5 months.

31. An assembly line of an item A has the following output in a 10 week period:

Week No	Standard hours Produced
1	350
2	375
3	380
4	400
5	300
6	325
7	340
8	370
9	390
10	350

Calculate the demonstrated capacity of the assembly line per week.

32. MTP

A workshop has 30 nos. of identical machines. From the failure pattern of the machines it is calculated that the expected time before failure is 3 months. It costs ₹200 to attend a failed machine and rectify the same. Compute the yearly cost of servicing the broken down machines. 2

33.

A steel plant has a design capacity of 25,000 tons of steel per day, effective capacity of 20,000 tons of steel per day and an actual output of 18,000 tons of steel per day. Compute the efficiency of the plant and its utilization. [2]

34.

The main shaft of an equipment has a very high reliability of 0.990. The equipment comes from Japan and has a high downtime cost associated with the failure of this shaft. This is estimated at ₹8 crores as the costs of sales lost and other relevant costs. However, this spare is quoted at ₹15 lakhs at present. Should the shaft spare be procured along with the equipment and kept or not?

Match the Following;

1.

Match the terms in Column I with the relevant terms in Column II. 0.5x8

Column I		Column II	
(A)	Benefit of Production Control	(i)	Reduced Manufacturing Cost
(B)	Limitations of Linear Programming	(ii)	Model of real phenomenon
(C)	Project Clean-up Phase	(iii)	Single Objective and Given Constraints
(D)	Simulation	(iv)	Balanced Inventory
(E)	Process Velocity	(v)	Voluntary group to identify problems
(F)	Quality Circle	(vi)	High reliability and rare requirement
(G)	Insurance Spares	(vii)	Value-added activities
(H)	Benefit of Work Study	(viii)	Dues are collected

Answer;

(A) (iv)
(B) (iii)
(C) (viii)
(D) (ii)
(E) (vii)
(F) (v)
(G) (vi)
(H) (i)

2.

Match List A with List B

List A	List B
a) Load Control	1) Product Mix determination
b) Linear Programming (LP)	2) Transportation Application
c) Vogel's Approximation Method (VAM)	3) Bottleneck Center

Answer;

List A	List B
a) Load Control	1) Bottleneck center
b) Linear Programming (LP)	2) Product Mix determination
c) Vogel's Approximation Method (VAM)	3) Transportation Application

3.

Match List A with List B [5 × 1 = 5]

List A	List B
a) ISO	1) Machine Tool
b) WIP	2) A programming language
c) CNC	3) Standardization
d) Java	4) A networking peripheral
e) Router	5) Production control

Answer;

List A	List B
a) ISO	1) Standardization
b) WIP	2) Production control
c) CNC	3) Machine Tool
d) Java	4) A programming language
e) Router	5) A networking peripheral

4.

Match the Activity/Operation in Column I with the machine/equipment in Column II.

	I		II
A.	Feeding coal continuously into the furnace in an Electric Power Station.	i.	Electromagnet
B.	Handling crates on Pallets within a factory.	ii.	Electric Arc Furnace
C.	Moving a heavy load above the machine on the shop-floor in a workshop.	iii.	Gravity Chute
D.	Transporting fertiliser packed in bags to a railway wagon/truck on the ground below.	iv.	Drilling Machine
E.	Making a small deep hole in block of metal.	v.	Plaining Machine
F.	Machining a large flat surface on metal.	vi.	E.O.T. Crane
G.	Melting steel for making castings.	vii.	Fork-lift Truck
H.	Picking up bits of iron and steel in a scrap yard.	viii	Belt Conveyor

Answer;

A: viii. Belt Conveyor

B: vii. Fork-lift Truck

C: vi. E.O.T. Crane

D: iii. Gravity Chute

E: iv. Drilling Machine

F: v. Planning Machine

G: ii. Electric Arc Furnace

H: i. Electromagnet

5.

Match the product in Column I with the production centre/equipment/plant in Column II.

I	II
A. Furniture	i. Assembly line
B. Hydro-electricity	ii. Refinery
C. Television set	iii. Foundry
D. Cement	iv. Carpentry
E. Rails	v. Smithy
F. Aviation Fuel	vi. Turbo-Alternator
G. Tools	vii. Blast Furnace
H. Castings	viii. Rotary Kiln
1. Forgings	ix. Rolling Mills
J. Pig Iron	x. Machine shop

Answer;

Matching:

I	II
A. Furniture	iv. Carpentry
B. Hydro-electricity	vi. Turbo-Alternator
C. Television Set	i. Assembly Line
D. Cement	viii. Rotary Kiln
E. Rails	ix. Rolling Mills
F. Aviation Fuel	ii. Refinery
G. Tools	x. Machine Shop
H. Castings	iii. Foundry
I. Forgings	v. Smithy
J. Pig Iron	vii. Blast Furnace

6.

Match the terms shown under 'X' with their relevant terms; shown under 'Y'.

X	Y
a. Ranking Method	1. Method Study
b. Motion Economy	2. Plant Layout
c. Work Sampling	3. Job Evaluation
d. Normal Curve	4. Material Handling
e. Use of Templates	5. Inventory Control
f. Gravity Chute	6. Statistical Quality Control
g. Crashing	7. Network Analysis
h. Replacement	8. Value Analysis
i. Brainstorming	9. Work Measurement
j. Stock Level	10. Maintenance

Answer;

Matching:

X	Y
a. Ranking Method	3. Job Evaluation
b. Motion Economy	1. Method Study
c. Work Sampling	9. Work Measurement
d. Normal Curve	6. Statistical Quality Control
e. Use of Templates	2. Plant Layout
f. Gravity Chute	4. Material Handling
g. Crashing	7. Net work Analysis
h. Replacement	10.Maintenance
i. Brainstorming	8. Value Analysis
j. Stock Level	5. Inventory Control

7.

Match the products in Column I with the production centers in Column II.

I	II
(A) Steam	(a) Blast Furnace
(B) Electricity	(b) Boiler
(C) Steel	(c) Generator
(D) Petrol	(d) Open Hearth Furnace
(E) Iron	(e) Refinery
(F) Cloth	(f) Assembly Line
(G) Car	(g) Smithy
(H) Castings	(h) Spinning Mill
(I) Cotton Yarn	(i) Foundry
(J) Forgings	(j) Power Loom

Answer;

Matching:

I	II
(A) Steam	(b) Boiler
(B) Electricity	(c) Generator
(C) Steel	(d) Open Hearth Furnace
(D) Petrol	(e) Refinery
(E) Iron	(a) Blast Furnace
(F) Cloth	(j) Power Loom
(G) Car	(f) Assembly Line
(H) Castings	(i) Foundry
(I) Cotton Yarn	(h) Spinning Mill
(J) Forgings	(g) Smithy

8.

I	II
A. Fork lift Truck	(a) move bulk material continuously
B. Jib crane	(b) move heavy loads over rectangular area
C. Belt Conveyor	(c) move heavy loads within a circular area
D. Electric Overhead Travelling crane	(d) move loads down
E. Gravity Chute	(e) move palletised unit loads

Answer

Matching	Particular
A — e	Fork lift Trucks move Palletised unit loads.
B — a	Jib cranes move bulk material continuously.
C — c	Belt Conveyors move heavy loads within a circula area.
D — b	Electric Overhead Travelling (EOT) cranes move heavy loads over rectangular area.
E — d	Gravity Chutes move loads down.

9.

Given below are two lists—list 'A' containing 11 abbreviations and list 'B' containing various functional areas associated with production management. Expand the abbreviations and match them with the corresponding functional areas.

List 'A'	List 'B'
LP	Capacity planning
PERT	Quality control
MTM	Project funding
VA	Project viability checking
CRAFT	Inventory management
SRAC	Product design
MRP	Cost control
CBA	Product mix determination
CAD	Plant layout
IFCI	Project planning
AOQ	Work measurement

Answer;

List 'A'	Expansion	Matching with List 'B'
LP	Linear Programming	Product mix determination
PERT	Programme Evaluation and Review Technique	Project planning
MTM	Methods Time measurement	Work measurement
VA	Value Analysis	Cost control
CRAFT	Computerised Relative Allocation of Facilities Technique	Plant layout
SRAC	Short Run Average Cost	Capacity planning
MRP	Materials Requirement	Inventory management
CBA	Cost Benefit Analysis	Project viability checking
CAD	Computer Aided Design	Product design
IFCI	Industrial Finance Corporation of India	Project funding
AOQ	Average outgoing Quality	Quality control

10.

Match the terms shown under 'X' with the relevant terms shown under 'Y'.

	X	Y
(i)	Foundry	(a) Gearbox
(ii)	Machine shop	(b) Value Analysis
(iii)	Brainstorming	(c) Electrode
(iv)	Automobile	(d) Lathe
(v)	Forge Shop	(e) Cupola
(vi)	Welding	(f) Power Hammer
(vii)	Heat Treatment	(g) Rubber
(viii)	Tyre Plant	(h) Hardening
(ix)	Assembly line	(i) Go-No Go gauge
(x)	Inspection1	(j) Conveyor

Answer ;

X	Y
(i) Foundry	(e) Cupola
(ii) Machine Shop	(d) Lathe
(iii) Brainstorming	(b) Value Analysis
(iv) Automobile	(a) Gearbox
(v) Forge Shop	(f) Power Hammer
(vi) Welding	(c) Electrode
(vii) Heat Treatment	(h) Hardening
(viii) Tyre Plant	(g) Rubber
(ix) Assembly Line	(j) Conveyor
(x) Inspection	(i) Go-No Go Gauge

11.

I	II
(a) UCL	(i) Work Measurement
(b) MTM	(ii) Project Management
(c) CPM	(iii) Public Sector
(d) LP	(iv) Quality Control
(e) BIS	(v) Optimisation
(f) FIFO	(vi) Standardisation
(g) MTBF	(vii) Reliability
(h) BPE	(viii) Inventory Management
(i) WIP	(ix) Cost Accounting
(j) VOH	(x) Production Control

Answer

(a) UCL	(iv) Quality Control
(b) MTM	(i) Work Measurement
(c) CPM	(ii) Project Management
(d) LP	(v) Optimisation
(e) BIS	(vi) Standardisation
(f) FIFO	(viii) Inventory Management
(g) MTBF	(vii) Reliability
(h) BPE	(iii) Public Sector
(i) WIP	(x) Production Control
(j) VOH	(ix) Cost Accounting

12.

List A	List B
LP	Product design
PERT	Quality control
MTM	Project funding
VA	Project viability checking
CRAFT	Inventory management
MRP	Cost control
CBA	Product-mix determination
CAD	Plant layout
IFCI	Project Planning
AOQ	Work measurement

Answer;

(i) LP — Linear Programming — Product mix determination.

(ii) PERT — Programme Evaluation and Review Technique — Project planning.

(iii) MTM — Methods Time Measurement — Work measurement.

(iv) VA — Value Analysis — Cost control.

(v) CRAFT — Computerised Relative Allocation of Facilities Techniques — Plant layout.

(vi) MRP — Materials Requirement Planning — Inventory management.

(vii) CBA — Cost Benefits Analysis — Project Viability checking.

(viii) CAD — Computer Aided (or Assisted) Design — Product Design.

(xi) IFCI — Industrial Finance Corporation of India — Project funding.

(x) AOQ — Average outgoing Quality — Quality control.

13.

Match the terms in column 1 with the relevant terms in column II.

I	II
(a) ISO	(i) Work Study
(b) PBT	(ii) Inventory Control
(c) CNC	(iii) Standardisation
(d) JIT	(iv) Profitability
(e) PMTS	(v) Machine Tool
(f) ESI	(vi) Computer Programme
(g) COBOL	(vii) Public Sector
(h) ITI	(viii) Welfare
(i) CPM	(ix) Employee Relations
(j) IR	(x) Project Management

Answer;

Answer

(a) ISO	(iii) Standardisation
(b) PBT	(iv) Profitability
(c) CNC	(v) Machine Tool
(d) JIT	(ii) Inventory Control
(e) PMTS	(i) Work Study
(f) ESI	(viii) Welfare
(g) COBOL	(vi) Computer Programme
(h) ITI	(vii) Public Sector
(i) CPM	(x) Project Management
(j) IR	(ix) Employee Relations

14.

Expand the following 10 abbreviations indicated in column X and then match the same with the most appropriate one indicated in Column Y on the right-hand side.

X	Y
SPT	Standardisation
ICICI	Labour related standards
ABC	Scheduling
ISO	Tax based on cost of additional processing
PPC	Venture Capital
LCL	Machines used for producing a class of products

SPM	Manufacturing planning and monitoring
VAT	Marketing strategy
USP	Statistical Quality Control
ILO	Classification based on annual usage value

Answer;

SPT	Shortest Processing Time — Scheduling
ICICI	Industrial Credit and Investment Corporation of India — Venture Capital
ABC	Always Better Control — Classification based on annual usage value
ISO	International Standards Organisation — Standardisation
PPC	Production Planning and Control — Manufacturing planning and monitoring
LCL	Lower Control Limit — Statistical Quality Control
SPM	Special Purpose Machine Tools — Machines for producing a class of products
VAT	Value Added Tax — Tax based on additional Cost of processing
USP	Unique Selling Proposition — Marketing strategy
ILO	International Labour Organization — Labour related standards

15.

Match each of the words in column I with the most appropriate ones from column II:

I	II
(A) Foundry	(a) Gauge
(B) Smithy	(b) Conveyor
(C) Machine shop	(c) Mould
(D) Welding	(d) Forge
(E) Heat treatment	(e) Lathe
(F) Assembly line	(f) Microscope
(G) Inspection	(g) Stacker
(H) Laboratory	(h) Furnace
(I) Design office	(i) Electrode
(J) Warehouse	(j) Pantograph

Answer;

I	II
(A) Foundry	(c) Mould
(B) Smithy	(d) Forge
(C) Machine shop	(e) Lathe
(D) Welding	(i) Electrode
(E) Heat treatment.	(h) Furnace
(F) Assembly line	(b) Conveyor
(G) Inspection	(a) Gauge
(H) Laboratory	(1) Microscope
(I) Design office	(j) Pantograph
(J) Warehouse	(g) Stacker

Problems;

Decision on Selection of Machine and Identification of Bottleneck;

1. Selection between Alternative Machines and Break Even Point;

Machines K and L, both capable of manufacturing an industrial product, compare as follows:

	Machine K	Machine L
Investment	₹60,000	₹1,00,000
Interest on borrowed capital	15%	15%
Operating cost (wages, power, etc.) per hour	₹12	₹10
Production per hour	6 pieces	10 pieces

The factory whose overhead costs are ₹1,20,000 works effectively for 4,000 hours in 2 shifts during the year.

(i) Justify with appropriate calculations which of the two machines you would choose for regular production.

(ii) If only 4000 pieces are to be produced in a year, which machine would give the lower cost per piece.

(iii) For how many pieces of production per year would the cost of production be same on either machine? (For above comparisons, the cost of material may be excluded as being the same on both machines.)

2. Selection of Machine

Machines A and B are both capable of manufacturing a product. They compare as follows:

Particulars	Machine A	Machine B
Investment	₹50,000	₹80,000
Interest on capital invested	15% per annum	15% per annum
Hourly charges (wages + power)	₹10	₹8
No. of pieces produced per hour	5	8
Annual operating hours	2,000	2,000

(i) Which machine will have the lower cost per unit of output, if run for the whole year?

(ii) If only 4,000 pieces are to be produced in a year, which machine would have the lower cost per piece?

(iii) Will your answer to (i) above query if you are informed that 12.5% of the output of machine B-gets rejected at the inspection stage. If so, what would be the new solution?

3. Break Even Quantity

Calculate the break-even point for the following:

Production Manager of a unit wants to know from what quantity he can use automatic machine against semi-automatic machine.

Data	Automatic	Semi-automatic
Time for the job	2 mts	5 mts
Set up time	2 hrs	1.5 hrs
Cost per hour	₹20	₹12

4. Determination of no. of Machines required;(CMA Inter June 2015 Similar)

A department works on 8 hours shift, 250 days a year and has the usage data of a machine, as given below:

Product	Annual demand (units)	Processing time (standard time in hours)
X	300	4.0
Y	400	6.0
Z	500	3.0

Determine the number of machines required.

5. Break-Even Point

A manager has to decide about the number of machines to be purchased. He has three options i.e., purchasing one, or two or three machines. The data are given below.

Number of machine	Annual fixed cost (₹)	Corresponding range of output
One	12,000	0 to 300
Two	15,000	301 to 600
Three	21,000	601 to 900

Variable cost is ₹20 per unit and revenue is ₹50 per unit

(a) Determine the break-even point for each range

(b) If projected demand is between 600 and 650 units how many machines should the manager purchase?

6. Selection of Set-up for Manufacture;

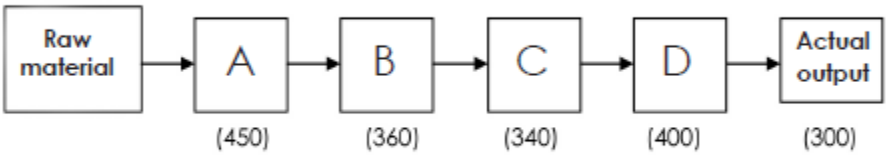
Two alternative set-ups, A and B are available for the manufacture of a component on a particular machine, where the operating cost per hour is ₹20.

Particulars	Set-up A	Set-up B
Components/set-up	4,000 pieces	3,000 pieces
Set-up cost	₹ 300	₹ 1500
Production rate/hour	10 pieces	15 pieces

Which of these set-ups should be used for long range and economic production?

7. Identification of Bottleneck with System Capacity and efficiency (CMA Inter 2009)

A firm has four work centres, A, B, C & D, in series with individual capacities in units per day shown in the figure below.



(i) Identify the bottle neck centre.

(ii) What is the system capacity?

(iii) What is the system efficiency?

8. Bottleneck Production Quantity

A department of a company has to process a large number of components/month. The process equipment time required is 36 minutes/component, whereas the requirement of an imported process chemical is 1.2 litres/component. The manual skilled manpower required is 12 minutes/component for polishing and cleaning. The following additional data is available:

	Availability/month	Efficiency of utilisation
Equipment hour	500	85%
Imported chemicals - Litres	1000	95%
Skilled manpower - hours	250	65%

(i) What is the maximum possible production under the current conditions?

(ii) If skilled man-power availability is increased by overtime by 20%, what will be the impact on production increase?

Replacement;

9.

The following table gives the running costs per year and resale values of a certain equipment whose purchase price is ₹ 6,500. At what year is the replacement due optimally.

Year	1	2	3	4	5	6	7	8
Running Cost (₹)	1,400	1,500	1,700	2,000	2,400	2,800	3,300	3,900
Resale Value (₹)	4,000	3,000	2,200	1,700	1,300	1,000	1,000	1,000

10.

A truck-owner finds from his past experience that the maintenance costs are ₹200 for the first year and then increase by ₹2,000 every year. The cost of the Truck Type A is ₹9,000. Determine the best age at which to replace, i.e. truck. If the optimum replacement is followed what will be the average yearly cost of owing and operating the Truck? Truck Type B cost ₹10,000. Annual operating costs are ₹400 for the first year and then increase by ₹800 every year. The Truck owner have now the Truck Type A which is one year old. Should it be replaced with B type, and if so, when?

11.

The data on the operating costs per year and resale prices of equipment A whose purchase price is ₹10,000 are given here:

Year	1	2	3	4	5	6	7
Operating Cost (₹)	1,500	1,900	2,300	2,900	3,600	4,500	5,500
Resale Value (₹)	5,000	2,500	1,250	600	400	400	400

(a) What is the optimum period for replacement?

(b) When equipment A is 2 years old, equipment B, which is a new model for the same usage, is available. The optimum period for replacement is 4 years with an average cost of ₹3,600. Should we change equipment A with that of B? If so, when?

12.

A firm has a machine whose purchase price is ₹20,000. Its maintenance cost and resale price at the end of different years are as given here:

Year	1	2	3	4	5	6
Maintenance Cost	1,500	1,700	2,000	2,500	3,500	5,500
Resale Price	17,000	15,300	14,000	12,000	8,000	3,000

(a) Obtain the economic life of the machine and the minimum average cost.

(b) The firm has obtained a contract to supply the goods produced by the machine, for a period of 5 years from now. After this time period, the firm does not intend to use the machine. If the firm has a machine of this type that is one year old, what replacement policy should it adopt if it intends to replace the machine not more than once?

13.

A machine X costs ₹5,000. Its maintenance cost is ₹1,000 in each of the first four years and then it increases by ₹200 every year. Assuming that the machine has no salvage value and the maintenance cost is incurred in the beginning of each year, determine the optimal replacement time for the machine assuming that the time value of money is 10% p.a.

14.

Following failure rates have been observed for a certain type of light bulbs:

Week	1	2	3	4	5
Per cent failing by the end of week:	10	25	50	80	100

There are 1,000 bulbs in use, and it costs ₹ 2 to replace an individual bulb which has burnt out. If all bulbs were replaced simultaneously it would cost ₹ 50 paisa per bulb. It is proposed to replace all bulbs at fixed intervals of time, whether or not they have burnt out, and to continue replacing burnt out bulbs as and when they fail. At what intervals all the bulbs should be replaced? At what group replacement price per bulb would a policy of strictly individual replacement become preferable to the adopted policy?

15.

An electric company which generates and distributes electricity conducted a study on the life of poles. The repatriate life data are given in the following table:

Life data of electric poles

Year after installation:	1	2	3	4	5	6	7	8	9	10
Percentage poles failing:	1	2	3	5	7	12	20	30	16	4

(i) If the Company now installs 5,000 poles and follows a policy of replacing poles only when they fail, how many poles are expected to be replaced each year during the next ten years?

To simplify the computation assume that failures occur and replacements are made only at the end of a year.

(ii) If the cost of replacing individually is ₹160 per pole and if we have a common group replacement policy it costs ₹80 per pole, find out the optimal period for group replacement.

16.

Suppose that a special purpose type of light bulb never lasts longer than 2 weeks. There is a chance of 0.3 that a bulb will fail at the end of the first week. There are 100 new bulbs initially. The cost per bulb for individual replacement is ₹ 1 and the cost per bulb for a group replacement is ₹ 0.50. It is cheapest to replace all bulbs: (i) individually, (ii) every week, (iii) every second week, (iv) every third week?

Staff Replacement;

17.

Problems concerning recruitment and promotion of staff can sometimes be analysed in a manner similar to that used in replacement problems in industry.

A faculty in a college is planned to rise to strength of 50 staff members and then to remain at that level. The wastage of recruits depends upon their length of service and is as follows:

Year	1	2	3	4	5	6	7	8	9	10
Total % who left up to:	5	35	56	65	70	76	80	86	95	100

the end of year

(i) Find the number of staff members to be recruited every year.

(ii) If there are seven posts of Head of Deptt. for which length of service is the only creterion of promotion, what will be average length of service after which a new entrant should expect promotion?

18.

A company plans to have a strength of 80 sales persons over time. The people employed by the company leave their job, the distribution of which is assumed to be as follows:

Year	1	2	3	4	5	6	7	8	9	10	11	12
% Expected to Leave by End of Period	5	18	35	45	62	75	88	90	95	96	99	100

Using this information, answer the following questions :

What recruitment level per annum would be necessary to maintain this strength?

Capacity Utilization;

19.

A worker works for 8 hours in each shift, but during that time he had clocked for 7 hours on the job. Calculate his utilization.

20.

Standard time for a task is 8 hours. Calculate the efficiency of a workman in the following cases:

(a) Worker completes the job in 10 hours.

(b) Worker completes the job in 6 hours.

21.

A workshop operates on 2 shifts of 8 hours per day. It has 10 machines. It works for 5 days in a week. Machine utilization is 90% and the efficiency of the machines is 85%. Calcutta the designed/ rated capacity of the workshop in standard hours.

22.

An assembly line of an item A has the following output in a 10 week period:

Week No	Standard hours produced
1	350
2	375
3	380
4	400
5	300
6	325
7	340
8	370
9	390
10	350

Calculate the demonstrated capacity of the assembly line per week.

23.

A manufacturing company has a product line consisting of five work stations in series. The individual workstation capacities are given. The actual output of the line is 500 units per shift.

Calculate (i) System capacity (ii) Efficiency of the production line

Workstation no.	A	B	C	D	E
Capacity/shift	600	650	650	550	600

24.

Penelope and Peter Legume own a small accounting service and one personal computer. If their customers keep organized records, either of the owners can use the computer to prepare one tax return per hour, on average. During the first two weeks of April, both Legumes work seven 12-hour shifts. This allows them to use their computer around the clock.

a. What is the peak capacity, measured in tax returns per week?

b. The Legumes normally operate from 9 A.M. to 7 P.M., five days per week. What is their effective capacity, measured in tax returns per week?

c. During the third week of January, the legumes processed 40 tax returns. What is their utilization, as percentage of effective capacity?

25.

You have been asked to put together a capacity plan for a critical bottleneck operation at the Surefoot Sandal Company. Your capacity measure is number of machines. Three products (men's, women's and children's sandals) are manufactured. The time standards (processing and setup), lot sizes, and demand forecasts are given in the following table. The firm operates two 8-hour shifts, 5 days per week, 50 weeks per year. Experience shows that a capacity cushion of 5 percent is sufficient.

Time Standards

Product	Processing (hr/pair)	Setup (hr/lot)	Lot Size (pair/lot)	Demand Forecast (pairs/yr)
Men's sandals	0.05	0.5	240	80,000
Women's sandals	0.10	2.2	180	60,000
Children's sandals	0.02	3.8	360	1,20,000

a. How many machines are needed?

b. If the operation currently has two machines, what is the capacity gap?

26.

A department of a company has to process a large number of components/month. The process equipment time required is 30 minutes/component and the manual skilled manpower required is 10 minutes/component. The following additional data is available:

	Availability/month	Efficiency of utilization
Equipment hour	400	80%
Skilled manpower-hours	250	65%

What is the maximum possible production under the current conditions?

27.

The following data are available for a manufacturing unit:

No. of operators	20
Daily working hours	8
No. of days per month	26
Std. production per month	300 units
Std. Labour hours per unit	8

The following information was obtained for June 2014:

Man days lost due to absenteeism	29
Unit produced	230
Idle Time	280 man hours

You are required to calculate the following: 2x4=8

(a) Percent absenteeism

(b) Efficiency of utilisation of labour

(c) Productive efficiency of labour

(d) Overall productivity of labour in terms of units produced per man per month.

Costing Problems;

28.

An item is produced in a plant having a fixed cost of ₹ 6,000 per month, variable cost of ₹2 per unit and a selling price of ₹7 per unit. Determine

(a) The break-even volume.

(b) If 1000 units are produced and sold in a month, what would be the profit?

(c) How many units should be produced to earn a profit of ₹ 4,000 per month?

29.

If a firm sells 5000 units, its loss is ₹ 10,000. But if it sells 9000 units, its profit is ₹10,000. Calculate its (i) Fixed Cost; (ii) BEP. 2

30.

Location A would result in annual fixed costs of ₹ 3,50,000 variable costs of ₹ 63 per unit and revenues ₹ 70 per unit. Annual fixed costs at Location B are ₹7,70,000 variable costs are ₹ 32 per unit and revenues are ₹ 65 per unit.

Sales volume is estimated to be 30,000 units/year. Calculate BEP for each location and determine which location will be attractive. 3+4=7

31.

Monthly demand for a component 8,000 units. Setting –up cost per batch ₹ 120. Cost of manufacture per unit ₹ 40. Rate of interest 10% P.a. Calculate the EBQ.

Work Study and Standard Time;

32.

The time study of a machinery operation recorded cycle times of 8.0, 7.0, 8.0 and 9.0 minutes. The analyst rated the observed worker as 90%. The firm uses a 0.15 allowance fraction. Compute the standard time.

33.

An 8 hours work measurement study in a plant reveals the following: Units produced = 320 nos. Idle time = 15%. Performance rating = 120%. Allowances =12% of normal time. Determine the standard time per unit produced.

34. For a certain element of work, the basic time is established to be 20 seconds. If for three observations, a time study observer records ratings of 100, 125 and 80 respectively, on a "100-normal scale", what are the observed timings?

35. Calculate the standard production per shift of 8 hours duration, with the following data. Observed time per unit = 5 minutes, Rating factor - 120%

Total allowances = $33\frac{1}{2}\%$ of normal time.

36. A work study practitioner who conducted a work sampling study assesses the activity level of a worker to be 70%. During the space of 8 hours working, this worker turns out 320 components. If the company policy is to inflate the normal time arrived at by work sampling study by 20%, what should be the allowed time per unit?

37. Calculate the standard time per article produced from the following data obtained by a work sampling study.

Total no. of observations = 2,500 No. of working observations = 2,100

No. of units produced in 100 hours duration = 6,000 numbers

Proportion of manual labour = 2/3

Proportion of machine time = 1/3

Observed rating factor = 115%

Total allowances = 12% of normal time

38. The work-study engineer carries out the work sampling study for 120 hours. The following observations were made for a machine shop:

Total number of observations	7000
No. of Idle activities	1200
Ratio between manual to machine elements	3 : 1
Average rating factor	120%
Total number of jobs produced during study	800 units
Rest and personal allowances	17%

Compute the standard time for the job. 6

39. An analyst wants to obtain a cycle time estimate that is within ± 5% of the true value. A preliminary run of 20 cycles took 40 minutes to complete and had a calculated standard deviation of 0.3 minutes. What is the coefficient of variation to be used for computing the sample size for the forthcoming time study?

40. Compute the production cost per piece from the following data,

(i) Direct material per piece - ₹ 2

(ii) Wage rate ₹ 2,000 per month consisting of 25 working days and 8 hours per day.

(iii) Overheads expressed as a percentage of direct labour cost - 200%.

(iv) The time for manufacture of 4 pieces of the item was observed during time study. The manufacture of the item consists of 4 elements a, b, c and d. The data collected during the time study are as under. Time observed (in minutes) during the various cycles are as below:

Element	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Element rating on B.S. Scale (0-1 00)
a	1.2	1.3	1.3	1.4	85
b	0.7	0.6	0.65	0.75	120
c	1.4	1.3	1.3	1.2	90
d	0.5	0.5	0.6	0.4	70

The personal, fatigue and delay allowance may be taken as 25%.

41.

Premabai undertakes knitting of sweaters for various shops. She has several helping hands who, besides knitting also carry out cleaning, disentangling woollen thread, measuring and cutting, sewing and customer contact activities. Hema, an enthusiastic industrial engineer, did an activities sampling (work sampling) study and came up with the following data:

Activity	No. of Observations
Knitting	120
Cleaning	40
Disentangling	75
Measuring and Cutting	20
Sewing	20
Speaking to Customers	25
Total No. of Observations	300

Hema rated the help she had observed at 95 for the disentangling activity and 100 for the knitting activity. If at the end of the four-day (36 work hours) study, Hema found that the helping hand had disentangled 2.3 kg of woollen thread and knitted a two meter-length equivalent, what are the standard times for these activities? Take total allowances at 25 per cent.

If Premabai gives the work of disentangling woollen thread to a helper for four hours, how much wool should be disentangled?

42.

Sonar Gold Fields miners at 10th level have an accepted production standard of two trolley-loads an hour in an eight-hour working day. In addition to the mining of the gold-bearing soil, the miners have to do a few routine jobs such as cleaning, sharpening and maintaining the tools, for which they are paid a wage of ₹9 per hour upto a maximum of two hours per day. The base wage rate of the miners engaged in production/mining job is ₹6.60 per hour.

If Subrato, a miner, produced 18 trolley-loads in addition to performing his routine tasks, what wages should he get at the end of the day?

43.

A manufacturing enterprise has introduced a bonus system of wage payment on a slab-rate based on cost of production towards labour and overheads.

The slab-rate being

Between 1% - 10%	Saving in production cost	5% of saving
Between 11%-20%	Saving in production cost	15%
Between 21%-40%	Saving in production cost	30%
Between 41%-70%	Saving in production cost	40%
Above 70%	Saving in production cost	50%

The rate per hour for three workers A, B, C are ₹5, ₹5.50 and ₹5.25 respectively. The overhead recovery rate is 500% of production wages and the material cost is ₹40 per unit. The standard cost of production per unit is determined at ₹160 per unit.
If the time taken by A, B, C to finish 10 units is 26 hours, 30 hours and 16 hours respectively, what is the amount of bonus earned by the individual workers and actual cost of production per unit?

44.

In a work sampling study, a mechanic was found to idle for 20% of the time. Find out the number of observation needed to conform to the above figures with a confidence level of 95% and a relative error level by ± 5%.

45.

A work sampling study is to be made of a typist pool. It is felt that typists are idle 30 percent of the item. How many observations should be made in order to have 95.5% confidence that accuracy is within ±4%.

46.

A job has been time standard for 20 observations. The mean actual time was 5.83 minutes and the standard deviation of the time is estimated to be 2.04 minutes. How many total observations should be taken for 95% confidence that the mean actual time has been determined within 10%?

47.

A work sampling study was performed on the activities of the customer care executives in a service organization. The observations are as under?

Activity	No. of observations
A1	250
A2	60
A3	100
A4	160
A5	50
A6	60
A7	50
A8	70
Total	800

The management of the organisation plans to eliminate activity "A4" by acquiring an EDP system. This, it is felt, will enable the executives' time to be better utilised. While the executives' salary on an average is ₹ 4,000 per month (25 working days), the volume of their time utilised (i.e., for more customer-care) is put at three times what their salary reflects. There are 200 executives in the organization and the EDP system is going to cost ₹ 75,000 a month covering the initial investment as well as operation expenses. Should the organisation go in for the EDP system? 6

48.

Calculate the standard time per article produced from the following data obtained by a work sampling study: 7

Total No. of observations = 2597

No. of working observations = 2000

No. of units produced in 100 hours duration = 5000 numbers

Proportion of manual labour = ¾

Proportion of machine time = ¼

Observed rating factor = 120%

Total allowances = 15% of normal time

Queuing

49.

Customers arrive at a bakery at an average rate of 16 per hour on weekday mornings. The arrival distribution can be described by a Poisson distribution with a mean of 16. Each clerk can serve a customer in an average of three minutes; this time can be described by an exponential distribution with a mean of 3.0 minutes.

a. What are the arrival and service rates?

b. Compute the average number of customers being served at any time.

c. Suppose it has been determined that the average number of customers waiting in line is 3.2. compute the average number of customers in the system (i.e., waiting in line or being served), the average time customers wait in line, and the average time in the system.

d. Determine the system utilization for M = 1,2, and 3 servers.

50.

An airline is planning to open a satellite ticket desk in a new shopping plaza, staffed by one ticket agent. It is estimated that requests for tickets and information will average 15 per hour, and requests will have a Poisson distribution. Service time is assumed to be exponentially distributed. Previous experience with similar satellite operations suggests that mean service time should average about three minutes per request.

Determine each of the following:

a. System utilization.

b. Percentage of time the server (agent) will be idle.

c. The expected number of customers waiting to be served.

d. The average time customers will spend in the system.

The probability of zero customers in the system and the probability of four customers in the system.

51.

Wanda's Car Wash & Cry is an automatic, five-minute operation with a single bay. One a typical Saturday morning, cars arrive at a mean rate of eight per hour, with arrivals tending to follow a Poisson distribution. Find

a. The average number of cars in line.

b. The average time cars spend in line and service.

52.

Shin's Car Wash & Dry is an automatic, five-minute operation with a single bay. On a typical Saturday morning, cars arrive at a mean rate of ten per hour, with arrivals tending to follow a Poisson distribution. Find the average number of cars in line.

Forecasting & Statistics

53.

The demand for sewing machine was estimated as 1000 per month for 5 months. Later on the actual demand was found as 900, 1050, 1000,1100 and 950, respectively. Workout MAD and Bias. Analyze whether the forecast made was accurate.

54.

Calculate the value of Tracking Signal for the demand overcast of sewing machine based on the actual demand data given in Illustration 1. State if the forecast for the demand of the sewing machines is under control.

55.

The following data on the exports of an item by a company during the various years fit a straight line, (for the time being, assume that a straight line gives a good fit). Give a forecast for the years 2014 and 2015.

Year	No. of items ('000)
2005	13
2006	20
2007	20
2008	28
2009	30
2010	32
2011	33
2012	38
2013	43

56.

Calculate the trend values by the method of least squares from the date given below and estimate the sales demand of milk for the year 2015-2016. 5

Year	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14
Sale of milk (in lakh litres)	20	25	27	35	38	41

57.

The demand for colour TV sets has been rising rapidly since colour transmission was introduced in 2003. The following data are for one of the metropolitan cities. Fit a quadratic curve to the data and forecast the demand during years 2012, 2013, 2014, 2015 and 2016.

Year	Demand ('000)
2003	25
2004	35
2005	50
2006	65
2007	85
2008	115
2009	150
2010	205
2011	285

58. Regression

Following is the data obtained from the Bureau of Industrial Costs and Prices. Have the prices kept pace with the rising costs?

	2004	05	06	07	08	09	10	11	12
Costs per unit of output	203	216	223	239	248	253	279	301	311
Price of final output	225	242	250	271	275	277	295	318	329

Repairs and Maintenance;

59.

PQR company has kept records of breakdowns of its machines for 300 days work year as shown below:

No. of breakdown	Frequency in days
0	40
1	150
2	70
3	30
4	10
	300

The firm estimates that each breakdown costs ₹ 650 and is considering adopting a preventive maintenance program which would cost ₹ 200 per day and limit the number of breakdown to an average of one per day. What is the expected annual savings from preventive maintenance program?

60.

The number of breakdowns of equipment over the past 2 years is as below :

No. of breakdowns	No. of month this occurred
0	3
1	7
2	9
3	3
4	2
Total	24

Each break down costs an average of ₹ 300. Preventive maintenance service can be hired at a cost of ₹ 150 per month and it will limit the breakdowns to an average of one per month. Which maintenance arrangement is preferable, the current breakdown maintenance policy or a preventive maintenance service contract?

Sequence in Machine;

61.

In a factory, there are six jobs to perform, each of which should go through two machines A and B, in the order AB. The processing timings (in hours) for the jobs are given here. You are required to determine the sequence for performing the jobs that would minimise the total elapsed time, T. What is the value of T?

Job	Machine A	Machine B
1	7	3
2	4	8
3	2	6
4	5	6
5	9	4
6	8	1

62.

The maintenance crew of a company is divided in two groups, C_1 and C_2, which cares for the maintenance of the machines. Crew C_1 is responsible for replacement of parts which are worn out while crew C_2 oils and resets the machines hack for operation. The times required by crews C_1 and C_2 on different machines which need working on them are given as follows:

Machine	Maintenance Time (Hrs.)	
	Crew C_1	Crew C_2
M_1	8	5
M_2	6	3
M_3	10	7
M_4	11	12
M_5	10	8
M_6	14	6
M_7	4	7

n what order should the machines be handled by crews C_1 and C_2 so that the total time taken is minimised?

63.

A company plans to fill six positions. Since the positions are known to vary considerably with respect to skill and responsibility, different types of aptitude tests and interviews are required for each. While the aptitude tests are conducted by people from the clerical positions, the lob interviews are held by the personnel from the management cadre. The job interviews immediately follow the aptitude test. The time required (in minutes) by each of the positions is given here,

Position	P_1	P_2	P_3	P_4	P_5	P_6
Aptitude Test	140	180	150	200	170	100
Job Interview	70	120	110	80	100	90

If it is desired to minimise the waiting time of the management personnel, in what order the position filling be handled?

64.

A firm works 40 hours a week and has a capacity of overtime work to the extern of 20 hours in a week. It has received seven orders to be processed on three machines A, B, and C, in the order A, B, C to be delivered in a week's time from now. The process times (in hours) are recorded in the given table:-

Job	:	1	2	3	4	5	6	7
Machine A	:	7	8	6	6	7	8	5
Machine B	:	2	2	1	3	3	2	4
Machine C	:	6	5	4	4	2	1	5

The manager, who, in fairness, insists on performing the jobs in the sequence in which they are received, is refusing to accept an eighth order, which requires 7, 2, and 5 hours respectively on A, B and C machines, because, according to him, the eight jobs would require a total of 61 hours for processing, which exceeds the firm's capacity. Advise him.

OR Part;

Simulation;

65.

In a simulation operation, a firm's maintenance person received requests for service and provided service during an 8 hour period as shown below:

Request Arrival Time (Clock Time)	Service Time (Hours)
0.00	1.0
0.30	1.0
2.00	1.5
3.00	1.5
6.30	0.5

The maintenance labour cost is ₹150 per hour, and the delay time cost is ₹500 per hour. Find:
(A) The idle time cost for the maintenance person, and
(B) The delay time cost for the machinery. 5

66.

Dr. Strong is a dentist who schedules all her patients for 30-minutes appointments. Some of the patients take more or less than 30 minutes depending on the type of dental work to be done. The following summary shows the various categories of work, their probabilities and the time actually needed to complete the work.

Category	Time Required	Probability of Category
Filling	45 Minutes	0.40
Crown	60 Minutes	0.15
Cleaning	15 Minutes	0.15
Extraction	45 Minutes	0.10
Check-up	15 Minutes	0.20

Simulate the dentist's clinic for four hours and determine average waiting time for the patients as well as the idleness of the doctor. Assume that all the patients show up at the clinic at exactly their scheduled arrival time starting at 8 a.m. Use the following random numbers for handling the above problem: 40, 82, 11, 34, 25, 66, 17, 79.

67.

A company manufactures around 150 mopeds. The daily production varies from 146 to 154 depending upon the availability of raw materials and other working conditions.

Production per Day	Probability
146	0.04
147	0.09
148	0.12
149	0.14
150	0.11
151	0.10
152	0.20
153	0.12
154	0.08

The finished mopeds are transported in a specially arranged lorry accommodating only 150 mopeds. Using following random numbers 80, 81, 76, 75, 64, 43, 18, 26, 10, 12, 65, 68, 69, 61, 57, simulate the process to find out:

(i) what will be the average number of mopeds waiting in the factory?

(ii) what will be the average number of empty spaces on the lorry?

68.

The Tit-Fit Scientific Laboratories is engaged in producing different types of high class equipment for use in science laboratories. The company has two different assembly lines to produce its most popular product 'Pressurex'. The processing time for each of the assembly lines is regarded as a random variable and is described by the following distributions.

Process Time (minutes)	Assembly A_1	Assembly A_2
10	0.10	0.20
11	0.15	0.40
12	0.40	0.20
13	0.25	0.15
14	0.10	0.05

Using the following random numbers, generate data on the process times for 15 units of the item and compute the expected process time for the product. For the purpose, read the numbers vertically taking the first two digits for the processing time on assembly A_1 and the last two digits for processing time on assembly A_2.

4134 8343 3602 7505 7428
7476 1183 9445 0089 3424
4943 1915 5415 0880 9309

69.

In a simulated operation, a firm's maintenance crew received requests for service and provided service during an 8 hour period as shown below :

Request arrival (clock) time	Service time (hours)
0.00	1.5
1.00	0.5
3.30	2.0
4.00	0.5
7.00	1.0

The maintenance labour cost is ₹ 140 per hour and the delay time cost is ₹ 450 per hour.

(a) Find the idle time cost for the maintenance crew.

(b) Find the delay time cost for the machinery.

70.

At a service station a study was made over a period of 50 days to determine both the number of automobiles being brought in for service and the number of automobiles serviced. The results are given below:

No. of automobiles arriving for service or completing services/day	Frequency of arrivals	Frequency of daily serviced
0	4	6
1	8	4
2	20	24
3	10	6
4	6	8
5	2	2

Simulate the arrival service pattern for a ten day period and estimate the mean number of automobiles that remain in service for more than a day.

Use the following series of random numbers:

For Arrivals	09	54	42	01	80	06	06	26	57	79
For Service	49	16	36	76	68	91	97	85	56	84

Assignment;

71.

Six salesmen are to be allocated to six sales regions so that the cost of allocation of the job will be minimum. Each salesman is capable of doing the job at different cost in each region.

The cost matrix is given below:

		Region					
		I	II	III	IV	V	VI
Salesmen	A	15	35	0	25	10	45
	B	40	5	45	20	15	20
	C	25	60	10	65	25	10
	D	25	20	35	10	25	60
	E	30	70	40	5	40	50
	F	10	25	30	40	50	15

(Figures are in Rupees)

(a) Find the allocation to give minimum cost what is the cost?

72.

A solicitor's firm employs typists on hourly piece-rate basis for their daily work. There are five typists and their charges and speed are different. According to an earlier understanding, only one job is given to one typist and the typist is paid for a full hour even when he works for a fraction of an hour. Find the least cost allocation for the following data:

Typist	Rate/hour(₹)	Number of Pages Typed/hour	Job	No. of Pages
A	5	12	P	199
B	6	14	Q	175
C	3	8	R	145
D	4	10	S	298
E	4	11	T	178

73.

Five swimmers are eligible to compete in a relay team which is to consist of four swimmers swimming four different swimming styles ; back stroke breast stroke, free style and butterfly. The time taken for the five swimmers – Anand, Bhaskar, Chandru, Dorai and Easwar- to cover a distance of 100 meters in various swimming styles are given below in minutes : seconds. Anand swims the back stroke in 1:09, the breast stroke in 1:15 and has never competed in the free style or butterfly. Bhaskar is a free style specialist averaging 1:01 for the 100 metres but can also swim the breast stroke in 1:16 and butterfly in 1:20. Chandru swims all styles – back storke 1:10, butterfly 1:12, free style 1:05 and breast stroke 1:20. Dorai swims only the butterfly 1:11 while Easwar swims the back stroke 1:20, the breast stroke 1:16, the free style 1:06 and the butterfly 1:10.

Required

Which swimmers should be assigned to which swimming style? Who will be in the relay?

74.

A company has four zones open and four marketing managers available for assignment. The zones are not equal in sales potentials. It is estimated that a typical marketing manager operating in each zone would bring in the following Annual sales:

Zones	*(₹)*
East	*2,40,000*
West	*1,92,000*
North	*1,44,000*
South	*1,20,000*

The four marketing manages are also different in ability. It is estimated that working under the same conditions, their yearly sales would be proportionately as under:

Manager M	*8*
Manager N	*7*
Manager O	*5*
Manager P	*4*

Transportation Problems;

75. Solve the following Table by initial basic solution

Destination / Source	A	B	C	D	Supply
1	3	1	7	4	300
2	2	6	5	9	400

3	8	3	3	2	500
Demand	250	350	400	200	

76.

Goods manufactured at 3 plants, A, B and C are required to be transported to sales outlets X, Y and Z. The unit costs of transporting the goods from the plants to the outlets are given below-

Plants / Sales Outlets	A	B	C	Total Demand
X	3	9	6	20
Y	4	4	6	40
Z	8	3	5	60
Total Supply	40	50	30	120

Required

(i) *Compute the initial allocation by North-West Corner Rule.*

(ii) *Compute the initial allocation by Vogel's approximation method and check whether it is optimal.*

(iii) *State your analysis on the optimality of allocation under North-West corner Rule and Vogel's Approximation method.*

77.

A product is manufactured by four factories A, B, C and D. The Unit production costs are ₹ 2, ₹ 3, ₹ 1 and ₹ 5 respectively. Their daily production capacities are 50, 70, 30 and 50 units respectively. These factories supply the product to four stores P, Q, R and S. The demand made by these stores are 25, 35, 105 and 20 Units transportation cost in rupees from each factory to each store is given in the following table;

Factories \ Stores	P	Q	R	S
A	2	4	6	11
B	10	8	7	5
C	13	3	9	12
D	4	6	8	3

Required

Determine the extent of deliveries from each of the factories to each of the stores so that the total cost (production and transportation together) is minimum.

78.

Ladies fashion shop wishes to purchase the following quantity of summer dresses:

Dress size	I	II	III	IV
Quantity	100	200	450	150

Three manufacturers are willing to supply dresses.

The quantities given below are the maximum that they are able to supply of any given combination of orders for dresses:

Manufacturers	A	B	C
Total quantity	150	450	250

The shop expects the profit per dress to vary with the manufacturer as given below:

Size

	I	II	III	IV
A	2.5	4.0	5.0	2.0
B	3.0	3.5	5.5	1.5
C	2.0	4.5	4.5	2.5

Required:

(a) Use the transportation technique to solve the problem of how the orders should be placed with the manufacturers by the fashion shop is order to maximise profit.

(b) Explain how you know there is no further improvement possible.

79.

XYZ Company has three plants and four warehouses. The supply and demand in units and the corresponding transportation costs are given. The table below shows the details taken from the solution procedure of the transportation problem:

Plants	*Warehouses*				*Supply*
	I	*II*	*III*	*IV*	
A	5	10	4 [10]	5	10
B	6 [20]	8	7	2 [5]	25
C	4 [5]	2 [10]	5 [5]	7	20
Demand	25	10	15	5	55

Required

(i) Is this solution feasible?

(ii) Is this solution degenerate?

(iii) Is this solution optimum?

LPP

80.

A Chemical Company produces two compounds A and B. The following table gives the units of ingredients C and D per kg of compounds A and B as well as minimum requirements of C and D and costs/kg of A and B. State the mathmetical formulation of the following:

		Table Compound		Minimum requirement
		A	B	
Ingredient	C	1	2	80
	D	3	1	75
Cost per kg.		4	6	

81.

A company sells two types of products, one is Super and the other is Delux. Super contains 5 units of chemical A and 2 units of chemical B per jar. Delux contains 3 units of each of chemical A and B per carton. The Super is sold for ₹ 7 per jar and the Delux is sold for ₹ 4 per carton.

A customer requires at least 150 units of chemical A and at least 120 units of chemical B for his business. How many of each type of the products should the customer purchase to minimize the cost while meeting his requirements?

Formulate LPP model for solving the above problem (do not solve it). 4

82.

Four Products — A, B, C and D have `5, `7, `3 and `9 as profitability respectively.
First type of material (limited supply of 800 kgs.) is required by A, B, C and D at 4 kg, 3 kg, 8 kgs and 2 kgs respectively per unit.
Second type of materials has a limited supply 300 kgs and is for A, B, C and D at 1 kg 2 kgs 0 kg and 1 kg per unit.
Supply of the other type of materials consumed is not limited. Machine hrs. available are 500 hours and the requirements are 8, 5, 0 and 4 hours for A, B, C and D each per unit.
Labour hours are limited to 900 hours and requirements are 3,2,1 and 5 hours for A, B, C and D respectively.
How should the firm approach so as to maximize its profitability?
Formulate this as a linear programming problem.
You are not required to solve the LPP. 6

83.

Maximise

$$Z = 100x_1 + 90x_2 + 40x_3 + 60x_4$$

Subject to

$$\begin{aligned} 6x_1 + 4x_2 + 8x_3 + 4x_4 &\leq 140 \\ 10x_1 + 10x_2 + 2x_3 + 6x_4 &\leq 120 \\ 10x_1 + 12x_2 + 6x_3 + 2x_4 &\leq 50 \\ x_1, x_2, x_3, x_4 &\geq 0 \end{aligned}$$

Required

Formulate the dual for the above problem. Only formulation is required. Please do not solve.

84.

If the Primal of a LPP is:
Max. $Z = 3x_1 + 5x_2 + 4x_3$
Subject to
$2x_1 + 3x_2 \leq 8$
$3x_1 + 2x_2 + 2x_3 \leq 10$
$5x_2 + 4x_3 \leq 15$,
And x_1, x_2 and $x_3 \geq 0$, What would be its dual? 4

Networking;

85.

Draw the network diagram for the activities of a maintenance job of a part of refinery

Table: Refinery Date

Activity	Description of Activity	Predecessor Activity
A	Dismantle the pipe line.	None
B	Disassemble other fittings.	A
C	Remove valves and check them.	B
D	Clean the valves and check them.	C,E
E	Clean the pipe lines and others.	B
F	Replace the defective items.	C, E
G	Layout of the assembly lines.	F
H	Assemble the valves.	G
I	Do the final connections.	H, D
J	Test the fittings.	I

86.

XYZ Auto-manufacturing company has to prepare a design of its latest model of motorcycle. The various activities to be performed to prepare design are as follows:

Activity	Description of activity	Preceding activity
A	Prepare drawing	—
B	Carry out cost analysis	A
C	Carry out financial analysis	A
D	Manufacture tools	C
E	Prepare bill of material	B, C
F	Receive material	D,E
G	Order sub-accessories	E
H	Receive sub-accessories	G
I	Manufacture components	F
J	Final assembly	I,H
K	Testing and shipment	J

Prepare an appropriate network diagram.

87.

Given the following information:

Activity	*Duration (in Days)*
0–1	*2*
1–2	*8*
1–3	*10*
2–4	*6*
2–5	*3*
3–4	*3*
3–6	*7*
4–7	*5*
5–7	*2*
6–7	*8*

Required

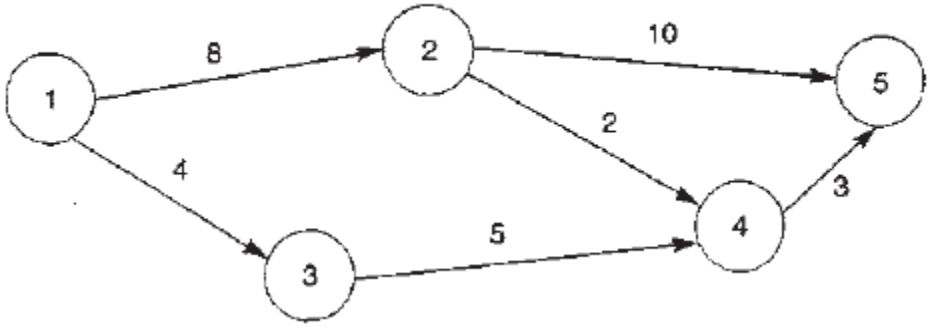
(i) Draw the arrow diagram.

(ii) Identify critical path and find the total project duration.

(iii) Determine total, free and independent floats.

88.

For given network find Total Float (TF), Free Float (FF) and Independent Float (IF)



89.

The activities involved in a project are detailed below:

Job	Duration (Weeks)		
	Optimistic	Most Likely	Pessimistic
1–2	3	6	15
2–3	6	12	30
3–5	5	11	17
7–8	4	19	28
5–8	1	4	7
6–7	3	9	27
4–5	3	6	15
1–6	2	5	14
2–4	2	5	8

Required

(i) *Draw a network diagram.*

(ii) *Find the critical path after estimating the earliest and latest event times for all nodes.*

(iii) *Find the probability of completing the project before 31 weeks?*

(iv) *What is the chance of project duration exceeding 46 weeks?*

(v) *What will be the effect on the current critical path if the most likely time of activity 3–5 gets revised to 14 instead of 11 weeks given above?*

(iii) *What is the probability that the project will be completed in 5 days earlier than the critical path duration?*

(iv) *What project duration will provide 95% confidence level of completion?*

90.

A project is composed of seven activities as per details given below:

Activity	Time Estimates (Days)		Cost Estimates (₹)	
	Normal	Crash	Normal	Crash
1–2	4	3	1,500	2,000
1–3	2	2	1,000	1,000
1–4	5	4	1,875	2,250
2–3	7	5	1,000	1,500
2–5	7	6	2,000	2,500
3–5	2	1	1,250	1,625
4–5	5	4	1,500	2,125

Indirect cost per day of the project is ₹ 500

Required

(i) *Draw the project network.*

(ii) *Determine the critical path and its duration.*

(iii) *Find the optimum duration and the resultant cost of the project.*

91.

For a network shown in figure, normal time, crash time, and normal costs are given in the table; construct the network by crashing it to optimum value and calculate the critical path, project duration, activities with least cost slope and optimum project cost. Indirect cost is given as ₹ 95 per day. 10

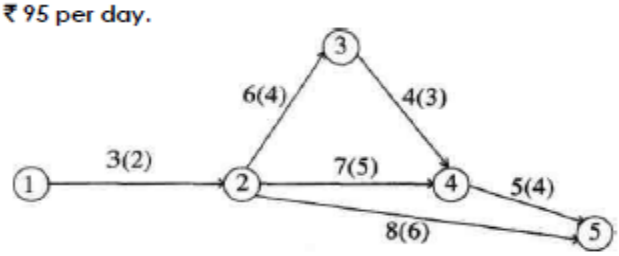


Table : Activity Relationship

Activity	Normal		Crash	
	Time (days)	Cost (₹)	Time (days)	Cost (₹)
1-2	3	300	2	400
2-3	6	480	4	520
2-4	7	2100	5	2500
2-5	8	400	6	600
3-4	4	320	3	360
4-5	5	500	4	520