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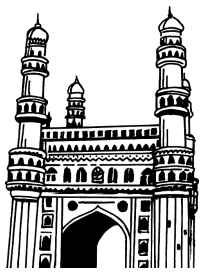

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MANAGEMENT SCIENCE

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UNIT I

INTRODUCTION TO PRODUCTION & OPERATIONS MANAGEMENT :

Definition of Production and Operations. An overview of Manufacturing processes: Functions of Production, Planning & Control. Interface of Product Life Cycle & Process Life Cycle. Process design – Project, Job, Batch, Assembly and Continuous process.

1.1 Definition of Production and Operations

Q1. Define production and operation management.

Ans :

Introduction

Production and Operations Management (POM) refers to the design, operation and enhancement of transformation process in which different inputs are converted into required outputs of products / services.

Today, the term 'operations management' is being used in place of 'Production and Operations Management'. The is because the production function which is related to manufacturing firms is now incorporated is operations. Operations management not only deals with manufacturing organizations but also the service organizations.

E.S. Buffa defines production management as follows:

'Production management deals with decision-making related to production processes so that the resulting goods or services are produced according to specifications, in the amount and by the schedule demanded and out of minimum cost'.

(i) Production

Production is a scientific process which involves transformation of raw material (input) into desired product or service (output) by adding economic value.

(ii) Operations Management

Operations management is the process which combines and transforms various resources used in the Production/Operations sub system of the organization into value added products /services in a controlled manner as per the policies of the organization.

The set of interrelated management activities which are involved in manufacturing certain products is called as production management. If the same concept is extended to services management, then the corresponding set of management activities is called as operations management.

Q2. Explain in brief the objectives of production management.

Ans : **(July-19, Dec.-18, Imp)**

Production is an organized activity in a manufacturing organization. Each organized activity must spell out its objectives so that its existence can be justified on the basis of the degree of the attainment of these objectives. Moreover, such dentification of the objectives increases the consciousness of the personnel working in the respective organizations in checking their efforts by verifying whether they are in conformity with the stated objective of the organization.

The objectives of the production function are classified as under:

(1) Ultimate objectives, and

(2) Intermediate objectives.

(1) Ultimate objectives

The primary responsibility of the manufacturing activity is to produce a product products at (1) pre-established cost, (2) according to the specified quality, and (3) within the stipulated time schedule.

Thus the ultimate objectives can be sub-classified as under:

(i) Manufacturing costs,

(ii) Product quality, and

(iii) Manufacturing time-schedule.

(i) Manufacturing costs

The unit cost of the product should be estimated carefully and every effort should be made to stick to the cost standards. For this purpose, the efforts should be made tc segregate the costs into two - direct costs and variable costs. Efforts should be made for the following:

(a) Reduction in the variable costs.

(b) Reduction in the fixed costs.

(c) Increase in the volume of production, so that the fixed costs may be spread over more production resulting in the reduction in the per unit absorption.

(d) The allocation of the fixed overheads should be made on scientific basis.

(ii) Product quality

Generally, the product quality standards are often established by the product specifications or by the consumers. The manu- facturing organization should try to translate such quality prescriptions into some measurable objectives. It should be noted that the product quality comes in conflict with the manufacturing cost objective and the manufacturing time-schedule. The maintenance of the quality should not result in increase in manufacturing costs or delay in the production. A proper balance must be maintained between quality and cost as well as quality and time-schedule.

(iii) Manufacturing schedule

There are many forces which compel side-tracking in the manufacturing activity. The time schedule should not be set for the shipment alone, it should be broken up into all the sub-systems like operating cycle time, inventory turnover rate, machine utilization rate, direct and indirect man-hours per unit, capacity utilization, machine and labour idle time, set-up, repair and maintenance time etc. Time schedule objective directly affects the cost, quality and the goodwill of the business in terms of regularity of shipment.

(2) Intermediate objectives

Production is the result of various types of inputs, like men, materials, machines and manufacturing services. The intermediate objectives strive to attain the optimum utilization of these various types of inputs. It should be noted that the output resulting out of the inputs is measured in terms of the cost, quality and time which relate to the prescription of aforesaid ultimate objectives. The intermediate goals can be spelled out as under:

(i) Machinery and equipment

(ii) Materials,

(iii) Manpower, and

(iv) Manufacturing services.

(i) Machinery and equipment

The objectives in the area of machinery and equipment are divided into:

(a) Acquisition of machinery and equipment, and

(b) Utilization of machinery and equipment.

The adequacy of the existing machinery should be considered and proper additions and replacements should be made according to the requirements.

Efforts should also be made to increase the utilization rate of machinery through repair, maintenance and maximum occupancy of the machines.

(ii) Materials

The materials objectives must be prescribed in terms of units, rupee value and space requirements. The per unit material costs should be specified and efforts should be made to increase the inventory turnover of all types of inventories - raw materials, work-in-progress and finished goods.

(iii) Manpower

Manpower is an important as well as typical input in manufacturing activities. So the objectives of the production activities are as regards manpower must be closely allied with the objectives of selection, placement, training, rewarding and utilization of manpower. Usually, these objectives are considered in terms of employee turnover rates, safety measurements, industrial relations, absenteeism etc.

(iv) Manufacturing services

The provision of proper and adequate services directly affects the utilization of other inputs such as men, machines and materials. Proper objectives should be set for the installation of important facilities such as power, water supply, material handling etc. In a condensed form, it can be stated that the objectives of the manufacturing activities are to manufacture a quality product, on schedule, at the lowest possible costs, with maximum asset turnover, to achieve consumer satisfaction. This statement is closely related to the ultimate and Intermediate objectives of the production function.

To summarise, production has to

- Make sure that it develops a product which can function as expected, i.e., product with the correct Quality,
- Produce the product in correct Quantity,
- Deliver the product in Time to the right Place,
- And to perform these functions at the right Price

Q3. Explain the framework of managing operations.

Ans : **(July-19, Imp.)**

Operations management involves planning, organizing, and supervising processes, and make necessary improvements for higher profitability. The adjustments in the everyday operations have to support the company's strategic goals, so they are preceded by deep analysis and measurement skills required to perform such work are as diverse as the function itself.

The most important skills are:

- **Organizational abilities.**

  Organizing processes in an organization requires a set of skills from planning and prioritizing through execution to monitoring. These abilities together help the manager achieve productivity and efficiency.

- **Analytic capabilities/understanding of process.**

  The capability to understand processes in your area often includes a broad understanding of other functions, too. An attention to detail is often helpful to go deeper in the analysis.

- **Coordination of processes.**

  Once processes are analyzed and understood, they can be optimized for maximum efficiency. Quick decision-making is a real advantage here, as well as a clear focus problem-solving.

- **People skills.**

  Flaws in the interactions with employees or member of senior management can seriously harm productivity, so an operation manager has to have people skills to properly navigate the fine lines with their colleagues. Furthermore, clear communication of the

tasks and goals serves as great motivation and to give a purpose for everyone.

- **Creativity.**

  Again, problem-solving skills are essential for a creative approach if things don't go in the right direction. When they do, creativity helps find new ways to improve corporate performance.

Q4. What are the characteristics of production and operations management?

Ans :

1. Manufacturing as Competitive Advantage

In the past production was considered to be like any other function in the organization. When demand was high and production capacities were inadequate, the concern was to somehow muster all inputs and use them to produce goods which would be grabbed by market.

2. Services Orientation

As was stated earlier, service sector is gaining greater relevance these days. The production system, therefore, needs to be organized keeping in mind the peculiar requirements of the service component. The entire manufacturing needs to be geared to serve (i) intangible and perishable nature of the services, (ii) constant interaction with clients or customers, (iii) small volumes of production to serve local markets, and (iv) need to locate facilities to serve local markets. There is increased presence of professionals on the production, instead of technicians and engineers.

3. Disappearance of Smokestacks

Commencing from Industrial Revolution till the middle of the 20th century, production system was dominated by smokestacks. These smokestacks (the term used by Alvin Toffler in his book Power Shift) represented industrial establishments which ejected thick smoke polluting the environment around. Smokestacks not only disgorged reek, they produced nauseating smell, generated dust, created sound and in general were resembling ghosts. Not that they have become extinct but are disappearing gradually.

4. Small has Become Beautiful

It was E.F. Schumacher who, in his famous book Small is Beautiful, opposed giant organizations and increased specialisation. He advocated, instead, intermediate technology based on smaller working units, community ownership, and regional workplaces utilizing local labour and resources. For him, small was beautiful. Businessmen, all over the world, did not believe in Schumacher's philosophy. Inspired by economies of scale, industrialists went in for huge organizations and mass production systems.

1.2 AN OVERVIEW OF MANUFACTURING PROCESSES

Q5. What do you mean by Manufacturing Processes?

Ans :

Introduction

Conversion is a function by which goods and services are produced. A typical production system comprises of three main components : inputs, transformation process and output.

(i) Inputs are men, materials, machines, instructions, drawings, paper work and instructions.

(ii) The transformation process involves operations, mechanical or chemical, to change/convert inputs into outputs.

(iii) Output is goods and services (e.g. products, parts, paper work, served customers etc.)

The combination of operations and activities stated above, employed to create goods and services, is known as manufacturing system.

Manufacturing Processes and Classification

Manufacturing processes are the steps through which raw materials are transformed into a product. The manufacturing processes can be broadly classified into three categories viz. shaping, joining and finishing processes as shown schematically in Figure.

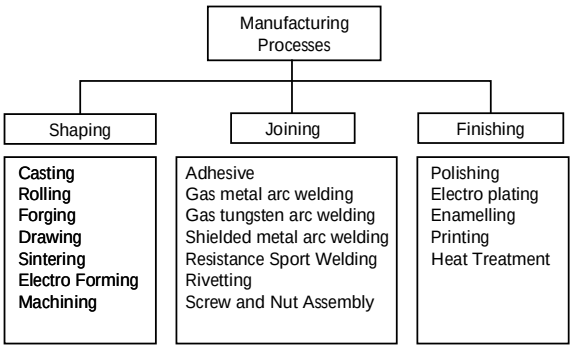

Fig. : Different classes of manufacturing processes

But the basic manufacturing process consist of the following concepts,

1. Casting
2. Machining
3. Welding
4. Shearing Extrusion
5. Heat Treatment
6. Unconventional Machining

1.2.1 Casting

Q6. Define Casting.

(OR)

What is Casting? Write the steps involved in casting process.

Ans :

Casting is the process for obtaining desired component by pouring molten metal in the mould cavity and allowing it to solidify.

Steps Involved in Casting

The various steps involved in making a casting are as follows,

1. Pattern preparation
2. Moulding
3. Melting and pouring the metal
4. Solidification
5. Removal of casting and fettling
6. Machining
7. Heat treatment
8. Finishing.

1. Pattern Preparation

A pattern is the replica of the final product required. Therefore, depending upon size, shape and casting process a pattern is prepared with either wood, metal or wax. Thus, pattern prepared must include all the allowances to obtain a sound casting.

2. Moulding

It is the main step as this involves making of cavity. The steps involved in moulding are as follows,

- Initially, drag is placed in the inverted position on moulding table as shown in figure.
- Pattern is then placed in suitable position insidethe drag.
- Parting sand is sprinkled on the pattern and all over the drag.
- Facing sand is poured only on pattern and it is pressed thoroughly on the pattern so that every detail of pattern is obtained.
- Backing sand is poured all over the drag and then rammed thoroughly. This is repeated till sand level reaches the surface of drag.
- Ramming should be done- all over the drag to get a better mould cavity.
- The excess sand can be removed using strike-off bar, to maintain a perfect surface level.
- Using a vent rod, vent holes are made which allows the air to escape.
- Cope is placed exactly above the drag and then parting sand is sprinkled over the pattern and sand.
- The sprue and riser are placed in position in the cope.
- Sprue is placed beside the pattern, whereas the riser should be directly above the pattern.
- Facing sand is poured around sprue and riser and pressed thoroughly to obtain steady position.

- Backing sand is poured all over cope and ramming is done.
- Excess sand is removed using strike-offbar and then venting is done.
- Sprue and risers are removed and pouring basin is cut using a gate cutter near the sprue.
- Cope is lifted and kept aside. Figure (2) shows the arrangement of cope and drag, after cutting runner and ingate in the drag.
- The pattern is slowly removed without disturbing the cavity.
- Again cope is placed over the drag. Thus, moulding is obtained i.e., cavity is obtained.

3. Melting and Pouring the Metal

a) Required metal is melted in oil furnace and then using the saddles molten are poured into cavity.

b) Molten metal is poured with uniform velocity as to obtain sound casting.

4. Solidification

In this step, after molten metal is poured, it is allowed to cool for certain duration, so that induced stresses can be reduced.

Solidification time actually depends on volume and surface area of casting.

5. Removal of Casting and Fetling

After the metal gets solidified, casting is removed from the mould and fetling is done. Fetling is cleaning operation of the cast using a brush to remove the sand particles on it.

6. Machining

a) The casting obtained has sprue, risers, ingates, basewell and pouring basin.

b) Thus, in this step all these are removed and desired product is obtained.

7. Heat Treatment

The casting so obtained may have stresses induced in it which may later affect the performance of the casting product.

Thus, heat treatment is done to relieve these induced stresses.

8. Finishing

It is the last step of casting process to obtain the dimensional accuracy and surface finish.

Q7. What are the advantages, disadvantages of casting.

Ans :

Advantages

1. Complex shapes can be produced by casting whereas it is not possible by other manufacturing processes.
2. There is no restriction to the type of metal to be casted as in other production processes there may be restrictions (Eg: Welding).
3. The plastics material can be casted very easily.
4. Surface finish of the product obtained by casting is too high.
5. Machining cost can be reduced.
6. Component achieves good mechanical properties after casting.
7. Cost of casting can be reduced by using mechanical and automatic casting process.
8. Large number of castings can be casted at a single time which intum increases the productivity.

Disadvantages

1. Time taking process.
2. In metal casting, metal needs to be melted which is a high energy consuming process.
3. The productivity is less than the other automatic processes, such as rolling.

Q8. What are the application of casting? Discuss the factors of casting?

Ans :

Applications

- Automobile engine blocks
- Cylinder blocks of automobile and aeroplane engines
- Pistons and piston rings
- Machine tool beds and frames

- Mill rolls, wheels and housings of steam and hydraulic turbines
- Turbine vanes and aircraft jet engine blades
- Water supply and sewer pipes
- Sanitary fittings and agricultural parts etc.

Factors

There are numerous factors that need to be considered to ensure proper size, shape and integrity of the final component. Some of these factors include :

1. Type of Material

Each metal and casting material retains specific characteristics (hardness, melting point, density, etc.) That will affect the casting process.

2. Cooling Rate

This factor depends largely on the type of material from which you craft the mold. Proper cooling is necessary to minimize gas porosity and other negative properties that can result from a fast cooling rate.

3. Shrinkage

As castings cool, they shrink. To ensure proper component size and integrity, you can utilize risers to feed additional molten metal into the cavity. An oversized mold may also be useful in some applications.

1.2.2 Machining

Q9. Define machining. Explain the classification of machining.

Ans :

Machine Tools are stationary power-driven machines used to shape or form solid materials, especially metals. The shaping is accomplished by removing material from a workpiece or by pressing it into the desired shape. Machine tools form the basis of modern industry and are used either directly or indirectly in the manufacture of machine and tool parts.

Machine tools may be classified under three main categories

1. Conventional chip-making machine tools.
2. Presses.
3. Unconventional machine tools.

1. Conventional chip-making machine tools

Conventional chip-making tools shape the workpiece by cutting away the unwanted portion in the form of chips.

2. Presses

Presses employ a number of different shaping processes, including shearing, pressing, or drawing (elongating).

3. Unconventional machine tools

Unconventional machine tools employ light, electrical, chemical, and sonic energy; superheated gases; and high-energy particle beams to shape the exotic materials and alloys that have been developed to meet the needs of modern technology.

General Lathe Machine Operations

The following are the general operations, that are performed on lathe machine,

- Turning (cylindrical or conical workpieces)
- Facing
- Grooving
- Drilling
- Reaming
- Counter sinking and counter boring
- Knurling
- Parting
- Thread cutting
- Chamfering
- Spinning
- Undercutting
- Milling

- Slotting
- Grinding
- Taper turning
- Scrolling
- Spring winding and
- Relieving
- Keyway cutting

Classification of Modern Machining Processes

The modem machining processes are classified based upon the following categories,

1. According to the type of energy

i) Mechanical
ii) Chemical
iii) Electro-chemical
iv) Electro thermal.

2. According to the mechanism of metal removal

i) Shear
ii) Erosion
iii) Spark erosion
iv) Vaporization
v) Ionic dissolution
vi) Chemical ablation etc.

3. According to source of energy

i) Elydrostatic pressure
ii) High current density
iii) High voltage
iv) Ionized material
v) Corrosive agent etc.

4. According to the medium for energy transfer

i) High velocity particles
ii) Electrolyte
iii) Electrons
iv) Hot gases
v) Radiations etc.

1.2.3 Welding

Q10. Define Welding. Give a classification of welding processes.

Ans :

Welding is defined as a technique of joining two dissimilar or similar metals by the application of heat and pressure. Welding processes are broadly classified into two types. They are,

1. Plastic (or) Pressure welding process
2. Fusion welding process.

1. Plastic (or) Pressure Welding Process

In pressure or plastic welding process, the metal to be joined are heated to plastic state and then external pressure is applied. This process is used in resistance welding, forge welding, thermit welding etc.

2. Fusion Welding Process

In fusion welding process, the metal to be joined is heated to molten state and allowed it to solidify. This process is used in gas welding, arc welding etc.

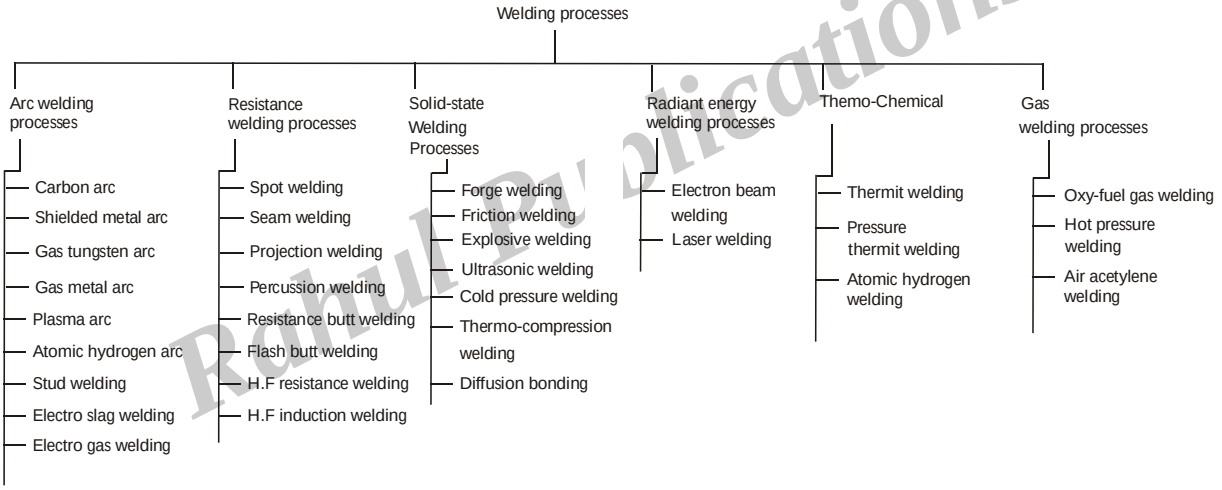

Fig.: Classification of Welding Processes

Some of the welding processes are defined below,

a) Gas Welding

Fusion welding process is used in gas welding, where two metals are joined by burning a combustible gas with air or oxygen in a concentrated flame of high temperature. Filler rod may be used to fill up the cavity during welding process.

b) Arc Welding

It is also a fusion welding process in which two metals are joined by heating with an electric arc to the melting temperature and then allowed it to solidify. Depending upon the thickness of base plate, filler metals may be used.

c) Resistance Welding

It is a pressure or plastic welding process, in which two metals are joined by passing a low voltage and very high current through the joint which melts the metals due to their contact resistance. External pressure is used to complete the weld. No filler metal is used.

d) Solid State Welding

It is a pressure or plastic welding process in which two metals are joined by heating the metal below its melting point temperature and then external pressure is applied.

e) Thermochemical Welding

It is primarily a pressure or plastic welding process in which two metals are joined by heat of thermit reaction and external pressure is applied to complete the weld.

f) Radiant Energy Welding

It is a fusion welding process in which a beam of electron strikes the surfaces to be joined and produces heat which causes the metals to melt and fuse.

1.2.4 Shearing Extrusion

Q11. Explain the concept of shearing extrusion.

Ans :

The concept of shearing extrusion consist of the following features,

1. Any cross-sectional shape can be extruded from the non-ferrous metal.
2. So extrusions can offer savings in both metal and weight.
3. Cross-sectional shapes are not possible by rolling.
4. A lot of time is lost when changing of shapes takes place. Since, the dies may be readily removed and replaced.
5. Dimensional accuracy of extruded parts is generally superior to that of rolled ones.
6. The range of extruded items is very wide and rods from 3 to 250 mm in diameter, pipes of 20 to 400 mm in diameter and wall thickness of 1 mm and above contains more complicated shapes which cannot be obtained by other mechanical working methods.
7. Very large reductions are possible as compared to rolling, for which the reduction per pass is < 2.
8. Automation of extrusion is simpler as items are produced in a single passing.

The extrusion equipment consists of a cylinder or container into which the heated metal workpiece is loaded as shown in figure. A die plate is fixed at one end of the container and the other end consists of a plunger or ram. The ram compresses the metal in the container and forces to flow through the die opening. The extruded metal coming out of the die acquires the shape of die and is carried by the metal handling system.

A dummy block with a diameter slightly less than the container is kept between the hot workpiece and the ram to protect it from the heat and pressure. The important parameter is the extruding force that depends on the material of the workpiece, extrusion ratio between the workpiece to chamber, die surfaces and process variables such as temperature of the workpiece, the extrusion speed.

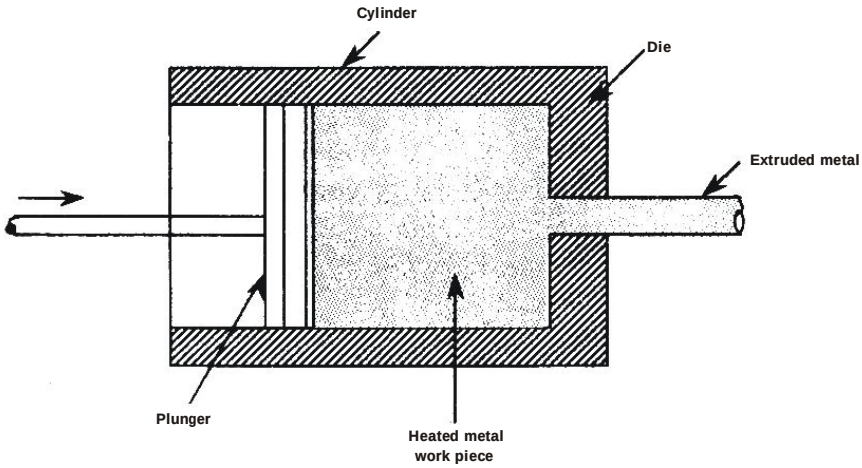

Fig. : Shearing Extrusion

The extrusion speed depends on the material of the work. High speed of extrusion results in excessive heat generation and causes cracking. At low extrusion speeds greater cooling of the workpiece occurs.

1.2.5 Heat Treatment

Q12. Define Heat Treatment. What are the various stages of heat treatment?

Ans :

"A combination of heating and cooling operations timed and applied to a metal or an alloy in the solid state to produce desired properties" is known as heat treatment. Heat treatment involves transformation or decomposition of austenite and the products obtained will determine the physical and mechanical properties. Heat treatment of steel involves, heating the material to a temperature above the critical range to form austenite. Heat treatment depends on,

- The temperature to which the material is heated.
- Rate of cooling.

Reasons for Heat Treatment

1. To produce required combination of microstructure and mechanical properties to fulfill its purpose.
2. Increases the corrosion and wear resistance, improves machinability, surface conditions and mechanical properties by refining the grain size, for relieving the internal stresses and softening the material. Various heat treatment processes used to modify the structure and properties are annealing, normalizing, hardening, tempering and surface hardening.

Stages

The process employed for controlled heating and cooling of the given material to change its microstructure and properties is termed as "heat treatment". In general, a heat treatment cycle has three stages. They are,

1. Heating
2. Soaking (maintaining the heat at constant rate) and
3. Cooling.

1. Heating

Steel is heated to austenite temperature at which its microstructure changes to austenite. The process used are annealing and normalizing.

2. Soaking

The temperature of austenite is held for a sufficient period to allow a uniform change in the properties throughout the cross-section and it carried out by austenizing.

3. Cooling

Steel from the austenite temperature is then cooled to room temperature. The rate of cooling depends on the desired properties associated with change in the size, form and nature. Examples are ferrite, pearlite etc. The purpose of heat treatment is to obtain a required microstructure, mechanical or physical properties of the steel being heat treated. Some of the purposes for heat treatment of steels are,

i) To relieve the internal stresses developed during cold working, casting, forging etc.

ii) Improve the hardness and strength.

iii) Improve electrical and magnetic properties.

iv) Improve ductility and toughness.

v) Soften the metals for other uses (cold working, rolling).

1.2.6 Unconventional Machining

Q13. Define unconventional machining. State the classification of unconventional machining.

Ans :

Material Removal Processes can be Divided into Two Groups

1. Conventional Machining Processes
2. Non-Traditional Manufacturing Processes (or) Unconventional Machining processes

1. Conventional Machining Processes

Conventional Machining Processes mostly remove material in the form of chips by applying forces on the work material with a wedge shaped cutting tool that is harder than the work material under machining condition.

2. Non-Traditional Manufacturing Processes (or) Unconventional Machining processes

Non-conventional manufacturing processes is defined as a group of processes that remove excess material by various techniques involving mechanical, thermal, electrical or chemical energy or combinations of these energies but do not use a sharp cutting tools as it needs to be used for traditional manufacturing processes. Material removal may occur with chip formation or even no chip formation may take place. For example in AJM, chips are of microscopic size and in case of Electrochemical machining material removal occurs due to electrochemical dissolution at atomic level.

Need for Unconventional Machining Processes

1. Extremely hard and brittle materials or Difficult to machine material are difficult to Machine by traditional machining processes.
2. When the work piece is too flexible or slender to support the cutting or grinding Forces when the shape of the part is too complex.

Classification

1. Mechanical Processes

- A abrasive Jet Machining (AJM)
- Abrasive Water Jet Machining (AWJM)
- Water Jet Machining (WJM)
- Ultrasonic Machining (USM)

2. Electrochemical Processes

- Electrochemical Machining (ECM)
- Electro Chemical Grinding (ECG)
- Electro Jet Drilling (EJD)

3. Electro-Thermal Processes

- Electro-discharge machining (EDM)
- Laser Jet Machining (LJM)
- Electron Beam Machining (EBM)

4. Chemical Processes

- Chemical Milling (CHM)
- Photochemical Milling (PCM)

Applications

1. This process is best suited for machining hard and brittle materials.
2. Cutting thin sections of hard material without any distortion.
3. These methods are very useful for machining metals which have low thermal conductivity and high melting point.
4. Micro drilling in hard materials like tungsten and ceramics.
5. Cutting complex geometries on the thin surface films for making integrated circuits.

Advantages

1. These methods are capable of machining metals and alloys irrespective of hardness, brittleness, strength and toughness of the materials.
2. Complex geometries and intricate shapes can be machined easily through this process.
3. The machined surface is free from burrs and residual stresses.
4. Brittle materials with high hardness can be machined.
5. Closed tolerances upto 0.05 mm can be easily obtained by these methods.
6. High surface finish in the range of 0.1 to 0.2 microns can be obtained.
7. Negligible wear of the tool.
8. Work material is not subjected to any distortions.
9. Metal removal rate is high compared to traditional machining.

1.3 PRODUCTION, PLANNING & CONTROL

Q14. Define the term production, planning and control.

(OR)

What do you mean by production planning & control?

Ans : **(Dec.-20, Imp.)**

Meaning

Production consists of a sequence of operations that transform materials from a given form to a desired form (products). The highest efficiency in production is obtained by manufacturing the required quantity of products, of the required quality, at the required time, by the best and cheapest method. To achieve this objective, production management employs production planning and control function which is a management tool that coordinates all manufacturing activities.

The four factors viz., quantity, quality, time and cost encompass the production system of which production planning and control (in short referred to as PPC) is the nerve centre or brain. There are three stages in PPC.

They are :

(i) Planning

The choice from several alternatives of the best means of utilizing the resources available to achieve the desired objectives in the most efficient and economic manner.

(ii) Operations

Performance in accordance with the details set out in the production plan

(iii) Control

The monitoring of performance through a feed back by comparing the results achieved with the planned targets so that performance can be improved through proper corrective action. This control mechanism is also responsible for subsequent adjusting, modifying and redefining plans and targets in order to ensure the attainment of goals.

Hence, 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.

Production planning and control is also referred to as operations-planning and control because the production planning and control techniques used in production systems manufacturing tangible goods can also be employed in operations or service systems providing services.

Q15. What are the factors determining production, planning and control.

Ans :

The production planning procedures used, varies from company to company. Production planning may begin with a product idea and a plan for the design of the product and the entire production/operating system to manufacture the product. It also includes the task of planning for the manufacturing of a modified version of an existing product using the existing facilities. The wide difference between planning procedures in one company and another is primarily due to the differences in the economic and technological conditions under which the firms operate. The three major factors determining production planning procedures are:

(i) Volume of Production

The amount and intensity of production planning is determined by the volume - character of the operations and the nature of the manufacturing processes. Production planning is expected to reduce manufacturing costs. The planning of production in case of custom order job shop is limited to planning for purchase of raw materials and components and determination of work centres which have the capacity of manufacturing the product. In high volume operations, extensive production planning is necessary in planning for design of both the product and the production processes in order to achieve substantial cost reduction when large no of products are produced.

(ii) Nature of Production Processes

In job shop, the production planning may be informal and the development of methods is left to the individual workman who is highly skilled. In high volume production many product designers, equipment designers, process engineers, and methods engineers are involved and they put enormous amount of effort in designing the product and the manufacturing processes.

(iii) Nature of Operations

Detailed production planning is required for repetitive operations, for example, in case of continuous production of a single standardized product.

The variants in manufacturing approach are :

(a) Manufacturing to order which may or may not be repeated at regular intervals.

(b) Manufacturing for stock and sell (under repetitive batch or mass production). Example: Manufacture of automobiles, watches, typewriters etc.

(c) Manufacturing for stock and sell, (under continuous process manufacturing). Example: Chemical and food products, soap, synthetic yarn etc.

The degree to which production planning is carried varies with the nature of the process.

Q16. What are the objectives of production, planning and control?

(OR)

Explain briefly the objectives of PPC.

Ans : **(Imp.)**

1. To deliver quality goods in required quantities to the customer in the required delivery schedule to achieve maximum customer satisfaction and minimum possible cost.
2. To ensure maximum utilization of all resources.
3. To ensure production of quality products.

4. To minimize the product through-put time or production/manufacturing cycle time.
5. To maintain optimum inventory levels.
6. To maintain flexibility in manufacturing operations.
7. To co-ordinate between labour and machines and various supporting departments
8. To plan for plant capacities for future requirements.
9. To remove bottle-necks at all stages of production and to solve problems related to production.
10. To ensure effective cost reduction and cost control.
11. To prepare production schedules and ensure that promised delivery dates are met.
12. To produce effective results for least total cost.
13. To establish routes and schedules for work that will ensure optimum utilization of materials, labour and equipments and machines and to provide the means for ensuring the operation of the plant in accordance with these plans.
14. The ultimate objective is to contribute to profit of the enterprise.

Q17. Explain the scope of PPC

Ans :

Production planning and control encompasses the following areas :

1. Materials

Planning for procurement of raw materials, components and spare parts in the right quantities and specifications at the right time from the right source at the right price. Purchasing, storage, inventory control, standardization, variety reduction, value analysis and inspection are the other activities associated with materials.

2. Methods

Choosing the best method of processing from several alternatives. It also includes determining the best sequence of operations (process plans) and planning for tooling, jigs and fixtures etc.

3. Machines and Equipments

Manufacturing methods are related to production facilities available in the production system. It involves facilities planning, capacity planning, allocation and utilization of plant and equipments, machines etc.

It also involves equipments replacement policy, maintenance policy and maintenance schedules, tools manufacture and maintenance of tools etc.

4. Manpower

Planning for man power (labour, supervisory and managerial levels) having appropriate skills and expertise.

5. Routing

Determining the flow of work material handling in the plant, and sequence of operations or processing steps. This is related to considerations of appropriate shop layout and plant layout, temporary storage locations for raw materials, components and semi finished goods, and of materials handling systems.

6. Estimating

Establishing operation times leading to fixation of performance standards both for workers and machines.

7. Loading and Scheduling

Machine loading is allocation of jobs to machines in conjunction with routing and with due consideration for capacity of machines and priority for jobs in order to utilize the machines to the maximum possible extent.

Scheduling ensures that parts, sub assemblies and finished products are completed as per required delivery dates. It provides a time table of manufacturing activities. It ensures balanced load on all work centres and ensures even flow of work through the manufacturing facilities.

8. Dispatching

This is concerned with the execution of the planning functions. It gives necessary authority to start a particular work which has already been planned under routing and scheduling functions. Dispatching is release of orders and instructions for the starting of production in accordance with the route sheets and schedule charts.

9. Expediting

Means chasing, follow up or progressing which is done after dispatching function. It keeps a close liaison with scheduling in order to provide an efficient feed back and prompt review of targets and schedules.

10. Inspection

This function is related to maintenance of quality in production and of evaluating the efficiency of the processes, methods and labour so that improvements can be made to achieve the quality standards set by product design.

11. Evaluating

The objective of evaluation is to improve performance. Performance of machines, processes and labour is evaluated to improve the same.

12. Cost Control

Manufacturing cost is controlled by wastage reduction, value analysis, inventory control and efficient utilization of all resources.

Q18. What are the principles of PPC?

Ans :

1. Type of production determines the kind of production planning the and control system needed.
2. Number of parts involved in the product affect 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'.

1.3.1 Functions

Q19. What are the functions of PPC?

(OR)

Explain the functions of Production Planning.

(OR)

Briefly explain the functions of production planning & control.

Ans : **(Dec.-20)**

Production Planning Functions

The main functions of production planning are:

(i) 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 (e.g., production budget is the basis for materials budget, capital equipment budge and manpower budget).

(ii) 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.

(iii) Scheduling

Involves fixing priorities for each job and determining the starting time and finishing 'or each operation, the starting dates and finishing dates for each part, sub assembly

nal assembly. Scheduling lays down a time table for production indicating the total required for the manufacture of a product and also the time required for carrying out deration for each part on each machine or equipment.

Objectives of scheduling are:

(a) To prevent unbalanced use of time among work centres and departments.

(b) To utilize labour such that the output is produced within established lead time or cycle time so as to deliver the products in time and complete production at minimum total cost.

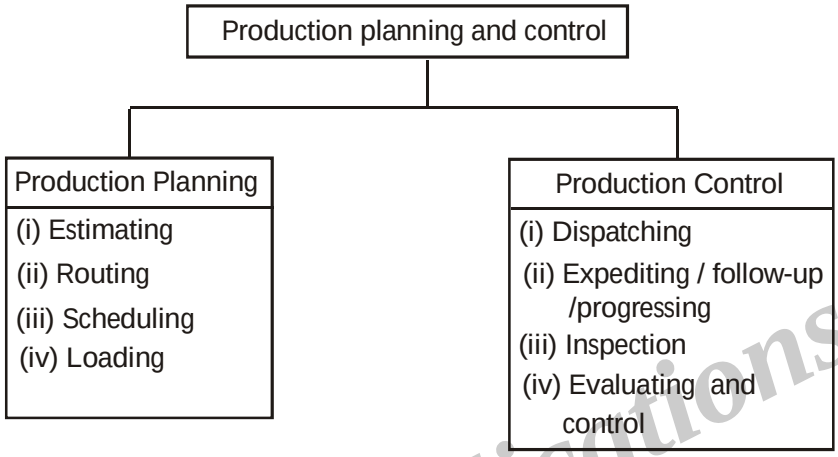

Fig.: Functions of PPC

(iv) Loading

Facility loading means loading of facility or work centre and deciding which jobs to be to which work centre or machine. Loading is the process of converting operation less into practice. Machine loading is the process of assigning specific jobs to machines, or work centres based on relative priorities and capacity utilization.

A machine loading chart (Gantt chart) is prepared showing the planned utilization of id machines by allocating the jobs to machines or workers as per priority sequencing establishes at the time of scheduling,

Production Control Functions

The control functions are:

(i) 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.

Dispatching also provides a means for comparing actual progress with planned production progress. Dispatching functions include

(a) Providing for movement of raw materials from stores to the first operation and from one operation to the next operation till all the operations are carried out.

(b) Collecting tools, jigs and fixtures from tool stores and issuing them to the use' department or worker.

(c) Issuing job orders authorizing operations in accordance with dates and times as indicated in schedules or machine loading charts.

(d) Issue of drawings, specifications, route cards, material requisitions and tool requisitions to user department.

(ii) Expediting/Followup/Progressing

Expediting or progressing ensures that the work is carried out as per plan and delivery schedules are met.

Progressing includes activities such as status reporting, attending to bottlenecks or hold ups in production and removing the same, controlling variations or deviations from planned performance levels, following up and monitoring progress of work through all stages production, co-ordinating with purchase, stores, tool room and maintenance deportments and modifying the production plans and replan if necessary

Need for expediting may arise due to the following reasons-

(a) Delay in supply of materials.

(b) Excessive absenteeism.

(c) Changes in design specifications.

(d) Changes in delivery schedules initiated by customers.

(e) Break down of machines or tools, jigs and fixtures.

(f) Errors in design drawings and process plans.

(iii) Inspection

It constitutes checking the quality of production process and analyzing the effectiveness of processes, methods and workers, so that desired quality can be achieved by making the necessary improvements.

(iv) Evaluation and Control

The entire process of manufacturing is evaluated to make the necessary improvement wherever that are required. It involves control of various activities like waste reduction, value analysis, inventory control and optimal exploitation of resources so as to reduce manufacturing cost.

Q20. Explain the limitations of PPC.

Ans :

(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 change frequently, 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.

Q21. What are the differences between production planning and production control.

Ans :

	PRODUCTION PLANNING	PRODUCTION CONTROL
1.	Planning involves collection and maintainance of data regarding time standards, materials and their specifications, machines and their quantities, tools and their process capabilities, drawings and operational layouts etc.	Control involves dissemination of data, preparation of reports regarding output, machine and labour fficiency, percentage defectives etc.
2.	Planning is seeing that requirements-tools, machines, men, instructions, authorisations and the like-tv///be available at the right time and in the right quantities and are of proper quality.	Control is seeing that the requirements are actually made available at the right place and in the right quantities.
3.	Planning involves preparation of load charts and fitting various work orders into uncommi-tted time available on the company's facilities (men or machines).	Control involves actual seeing that the jobs are started and completed as per schedule prepared by the scheduling cell of the PPC.
4.	Planning involves preparation of all necessary forms and paper work.	Control involves actual issue of forms and paper work.
5.	Planning involves designing suitable feed back as to what may happen.	Control involves keeping track of what is happening and collecting information as to what has happened .

1.4 Interface of Product Life Cycle & Process Life Cycle

Q22. Explain briefly about product life cycle.

(OR)

What are the various stages of product life cycle?

(OR)

Briefly explain various stages of product life cycle.

Ans : **(Dec.-20, July-19, Dec.-18, Imp.)**

A new product progresses through a sequence of stages from introduction to growth, maturity, and decline. This sequence is known as the product life cycle and is associated with changes in the marketing situation, thus impacting the marketing strategy and the marketing situation, thus impacting the marketing strategy and the marketing mix.

The product revenue and profits can be plotted as a function of the life-cycle stages as shown in the graph below:

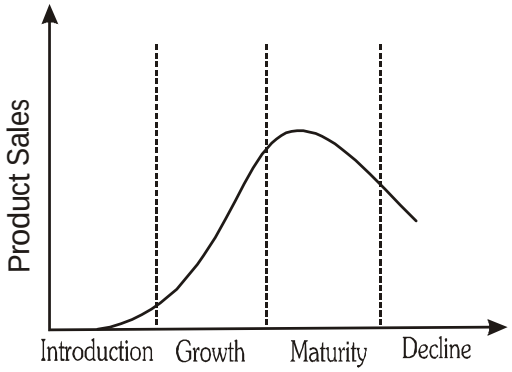

Fig.: Stages of product life cycle

1. Introduction Stage

In the introduction stage, the firm seeks to build product awareness and develop a market for the product. The impact on the marketing mix is as follows:

- **Product** branding and quality level is established, and intellectual property protection such as patents and trademarks are obtained.
- **Pricing** may be low penetration pricing to build market share rapidly, or high skim pricing to recover development costs.
- **Distribution** is selective until consumers show acceptance of the product.
- **Promotion** is aimed at innovators and early adopters. Marketing communications seeks to build product awareness and to educate potential consumers about the product.

2. Growth Stage

In the growth stage, the firm seeks to build brand preference and increase market share.

- **Product** quality is maintained and additional features and support services may be added.
- **Pricing** is maintained as the firm enjoys increasing demand with little competition.
- **Distribution** channels are added as demand increases and customers accept the product.
- **Promotion** is aimed at a broader audience.

3. Maturity Stage

At maturity, the strong growth in sales diminishes. Competition may appear with similar products. The primary objective at this point is to defend market share while maximizing profit.

- **Product** features may be enhanced to differentiate the product from that of competitors.
- **Pricing** may be lower because of the new competition.
- **Distribution** becomes more intensive and incentives may be offered to encourage preference over competing products.
- Promotion emphasizes product differentiation.

4. Decline Stage

As sales decline, the firm has several options:

- Maintain the product, possibly rejuvenating it by adding new features and finding new uses.
- Harvest the product - reduce costs and continue to offer it, possibly to a loyal niche segment.
- Discontinue the product, liquidating remaining inventory or selling it to another firm that is willing to continue the product.

The marketing mix decisions in the decline phase will depend on the selected strategy. For example, the product may be changed if it is being rejuvenated, or left unchanged if it is being harvested or liquidated. The price may be maintained if the product is harvested, or reduced drastically if liquidated.

Q23. Discuss in detail about process life cycle.

Ans : **(Dec.-19, Imp.)**

1. Job Shop Technology

It is used in the start up stage of process life cycle as it is suitable for producing small batches of variety of products wherein each product is designed conventionally and ultimately needs its unique set of processing steps which are to be carried out through out the complete production process.

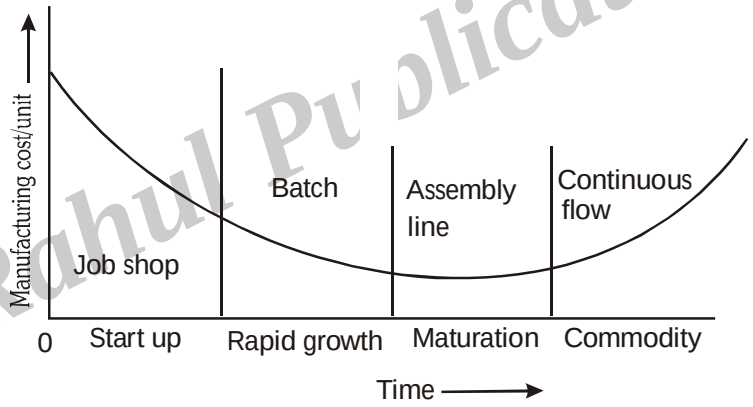

Fig. : The Process Life Cycle

2. Batch Technology

It is used in second stage of process life cycle. It is used in rapid growth stage because batch facilities are best suitable in situations wherein wide range of products are demanded again and again and in large volumes. Batch technology is suitable to produce a wide range of products in wide variety of volumes.

3. Assembly Line Technology

It is used in the maturation stage as it helps in producing limited range of standardized products in high volume.

At this stage of process life cycle, product designs are comparatively stable and advanced equipment, experienced human skills and management systems are developed and focused upon the limited range of products and volumes.

4. Continuous Flow Technology

It is used when product turns into a commodity in process life cycle. In this stage, the products and materials are produced in continuous and endless flow manner. In this stage, products become highly standardized with the help of continuous flow technology which provides a high volume continuous operation with capital intensive specialized automation.

Q24. State the relationship between product life cycle and process life cycle.

(OR)

Distinguish between product lifecycle and process life cycle.

Ans : **(Dec.-19)**

As the product develops and passes through different stages of life cycle, the productive system also passes through its own life cycle from job-shop system (or process focussed system to order,). When the product passes from initial stages to intermediate stages to a continuous system, the demand of the product is high.

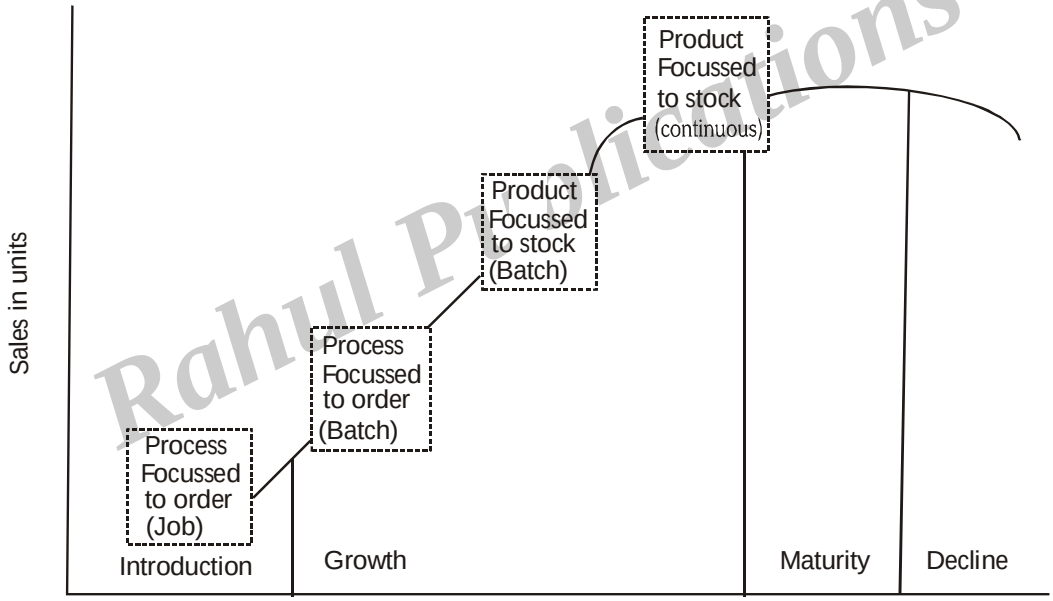

Fig. : Different Stages of Development

The different stages of product and process development are dependent on each other. The productive system depends on the product volume which is sold. The product volume which is sold depends on the costs and price related to the competitive position of quality and this costs and price depends on the use of effective productive system. The factors used in the productive system help in decreasing the costs and are essential elements of the competitive strategies of the manager. The reduction in costs can be useful for aggressive pricing which helps in developing market share, building experience etc. Process life cycle is developed by using various levels of process technology at each development stage. The process technology should show the need for flexibility when there are low volume dealing with wide varieties in the product design.

1.5 Process Design

Q25. Define process design. Explain importance of process design.

(OR)

What is process design? State the importance of process design.

Ans : **(Dec.-20)**

Meaning

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 organization's resources to provide something of value. No product can be made and no service can be provided without a process and no process can exist without a product or service.

Process design is concerned with the overall sequences of operations required to achieve tfff design specifications of the product. It specifies the type of work stations that are to be used, the machines and equipments necessary to carry out the processes to produce the product. The choice of process technology (i.e., manual, mechanized or automated technology) and the process design is related to product design because the manufacturing processes must be capable of achieving the product quality (accuracy, tolerance etc.) specified in the product design and also the product must be designed for productivity.

Importance

- New products are not realities until they are manufactured.
- Process design is necessary to manufacture new products.
- Process design means the complete delineation and description of specific steps in the production process and linkage among the steps that will enable the production system to produce products systems to produce products of the desired quality, in the required quantity.
- Process planning is intense for new product, but replanting can also occur as capacity needs change.

Q26. What are the major factors affecting process design decisions.

Ans :

Operations managers generally make process-design decisions after taking into consideration several factors.

Some of these factors are :

1. Nature of demand
2. Degree of vertical integration
3. Flexibility
4. Degree of Automation
5. Quality level and degree of customer contact.

A brief description of each of these factors and their influence on the process design decisions of an organization are given below.

1. Nature of Demand

The main objective of any production system is to produce products or services, according to customer requirements. Therefore, it is essential for an organization to schedule its production in such a way that it can always meet estimated future demand levels.

a) Influence of demand patterns

The demand for a product does not follow a fixed pattern over time. The rise or fall of demand over time is influenced by several factors, such as seasonal fluctuations, which affect the design of the production process of the product.

b) Influence of price level

In most countries, customers are price-sensitive in their purchases. They buy more of a product when the price is set low, but tend to buy lower volumes when the price level is set high.

2. Degree of Vertical Integration

One of the prime considerations of an operations manager when developing production-process designs is the level of vertical integration. Vertical integration refers to the extent to which the production and the distribution chain is brought under the ownership of the organization.

3. Flexibility

An organization is said to be flexible only when it responds quickly to changing customer needs or market conditions. Flexibility is essential for organizations to increase or maintain their market share. Flexibility can be broadly classified into two types: Product/ service, flexibility and volume flexibility.

a) Product/service flexibility

Product/service flexibility is the ability of the production system to shift quickly from producing one product to another. Some business strategies call for the production of many custom-designed products/services, in small lots.

Product/service flexibility is required in such cases. To produce different products in small lots, in most cases, general-purpose equipment and multi-skilled employees are used. The employees have to be trained so that they can perform different types of jobs.

b) Volume flexibility

Volume flexibility is the ability to increase or decrease production volumes rapidly in response to external changes. Volume flexibility is necessary for organizations which manufacture products whose demand fluctuates, because it is not economical to maintain a high level of inventory of such products.

The production processes for such organizations must be designed such that increasing or decreasing production levels is easy. The equipment for such organizations should be designed to meet the production requirements that are close to the peak levels of demand.

4. Degree of Automation

In the past, automating production processes was very costly. It was also difficult to integrate automated processes with other production processes. For these reasons, managers in the past tended to avoid automation. But, today, operations managers have realized that if automation is not made a strategic weapon, it will be a strategic limitation for their operations. Automation has become essential for organizations to become or remain competitive.

5. Quality Level and Degree of Customer Contact

The level of quality of a product or service decides whether it can compete in a market. Decisions taken on the desired quality level of products/services affect the design of the production process at all stages. The desired level of quality has a direct implication on the degree of automation to be built into the production process.

1.5.1 Project Process

Q27. Define Project Process. State the features of Project Process.

Ans :

Meaning

The project process is featured by high level of customisation of job, greater scope for project and the necessity of the substantial resources for the project completion.

Example

Construction of dams, factories, hospitals, development of new products and so on.

The projects are usually sophisticated in nature and involves greaters time for completing and include greater number of difficult activities.

Features

The various features of project are,

1. A project has both the start and the end points. It is a separate entity.
2. Project is a non-repetitive task and not a permanent entity.
3. These tasks can be broken into recognized activities which need resources and times for their implementation.
4. It needs to be completed on a specified date.
5. The objectives and the output are clear and definite.
6. They are complex in nature and involve a time period of at least 2 to 3 years or 6 months or few projects may also have time duration of 10 years.
7. Huge investment is needed.
8. The project consists and its completion are always subjected to few risks and uncertainties.
9. A project consists of three phases (i.e.,) planning, scheduling and controlling and these phases make use of the two techniques known as PERT (Project Evaluation and Review Technique) and CPM Critical Path Method)
10. The PERT projects are launching/introducing a new product in the market research and development of a new war weapon, launching the satellite and so on. The examples of CPM projects are construction of roads, bridges, buildings etc.

Q28. State the advantages and disadvantages of project process.

Ans :

Advantages

The various advantages of the project are,

1. The project management is useful in scheduling the production system.
2. Various network models are helpful in scheduling complex projects.
3. Various techniques of project management are useful in ascertaining the probability of completing the project on or before deadline.
4. The project management techniques are also used to determine the time period which is required to complete the project.
5. Project helps in designing and marketing the new product efficiently.
6. The corporate merger can be also carried out easily with the help of project management.
7. Long term planning of projects can be done effectively.
8. The delays in the job are reduced.

Disadvantages

The various disadvantages of the project management are as follows,

1. As the projects consist of various activities, and make use of different techniques, the time duration of each activity can be determined, but there exist several projects for which it may not be applicable.
2. It is assumed that the durations of activity are independent which may not be always possible.
3. During the project scheduling, several resources are required such as equipment, manpower and money, but these resources are limited which would result into several problems.
4. The estimation costs are very high.
5. The variable costs involved are also high.
6. The scheduling of the project is complex and is subjected to various variations.
7. The project process is difficult to plan and control resources, cost and time of completion.

1.5.2 Job Process

Q29. Define Job Process. State the characteri stics of Job Process.

Ans : **(Dec.-18, Imp.)**

Meaning

The job shop production system deals with producing the products for fulfilling the customer needs or requirements. In this system, all the orders

need different processes and different sequences of technological order.

Characteristics

The different characteristics of job-shop production system are as follows,

1. The job shop production system helps in producing several different jobs in small batches.
2. In the job shop production system, a single complete unit is produced with the help of group of operators and processes according to the orders of the customers.
3. The product which is manufactured in job shop production system is costly and non-standardized. Example: Electric power plant, dams construction, machine shop, sheet metal etc.
4. Job shop production system assembles equipments and machines at one place for huge objects.
5. In the job shop production system, general purpose equipments are used which helps in producing various jobs by using the same machinery.
6. In the job shop system, the material in process follows different patterns of processing in batches with the help of shop facilities.
7. In the job shop system, the job moves through various routes based on the work which has to be done.
8. A job shop system has to be managed by highly skilled workers.

Q30. What are the advantages and disadvantages of job process.

Ans :

Advantages

The following are the advantages of job-shop-production,

1. The job shop production system requires small amount of investment in equipments and machinery.
2. It is flexible in nature.
3. In the job shop system, a mistake or defect in one operation, does not interrupts the whole process.
4. It involves less managerial problems.
5. It can be started easily.
6. The risk involved is less, and the chances of failure are also less.

Disadvantages

Job shop system has the following disadvantages,

1. The production system of job shoo system is very complicated.
2. It needs an elaborate schedule of activities.
3. The job shop system faces difficulty in loading the machines.
4. It requires high inventories
5. The cost of material handling involved in job shop system is high.
6. Highly skilled machine operators are needed for managing the job shop system.
7. There are unbalanced work loads in job shop system.
8. As the raw materials are purchased on the basis of the order, its cost is high.

1.5.3 Batch Process

Q31. Explain the concept of Batch Process production.

Ans :

Meaning

A batch manufacturing facility produces some intermediate varieties of products with intermediate volumes. The volume of any single product may not be sufficient to justify the use of a dedicated set of equipments for its production. Under this condition, a few or several products will have to share the production resources to balance their utilization. Production equipment in batch

manufacturing must be capable of performing a variety of tasks, but the range of possible operations is much narrower than in a job shop.

Advantages

- Cheaper to produce a whole batch of a product than a single item at a time
- Machinery can be utilized more efficiently, therefore saving money for the business
- Reduces the risk of concentrating on one product and allows for flexibility
- The overall wastage is reduced by creating the correct number of products required

Disadvantages

- Each batch can be subject to meticulous quality control and assurances, potentially causing increased employee downtime
- Increased storage costs for large quantities of produced products
- Errors with the batch produced will incur wasted time and cost
- Periods of downtime where the specialist machinery must be altered. I.e. workers sitting idle and can be considered inefficient if you're solely relying on the machines for this process

1.5.4 Assembly Process

Q32. Describe briefly about Assembly Process.

(OR)

What are the advantages and Limitations of Assembly process.

Ans :

When different parts or assemblies are manufactured with the help of a continuous process, then it is known as mass production. Usually the machines are organized in lines in the mass production.

In this type of production, machines are organized in the form of a line or product layout and it involves a very large volume of production. Mass production includes both product and process standardization and similar path is followed by all outputs.

Characteristics

Following are the situations wherein mass production is used,

1. In sequencing the product and process standardization.
2. Where production is carried out in large volumes.
3. Where the cycle time of production is short.
4. Where the special purpose machines are used which have the higher production capacities and output rates.
5. Where process inventory is less.
6. Where production lines are perfectly balanced.
7. Where materials, components and parts have continuous flow without any backward movement.
8. Where production planning and control is easier to deal with.
9. Where material handling is carried out automatically.

Advantages

Mass production holds the following advantages,

1. The rate of production is high in mass production with less cycle time.
2. Proper utilization of the capacity with the help of line balancing.
3. Mass production does not require high skilled workers, it can be carried out with the help of semiskilled or low skilled operators or workers.
4. Less process inventory.
5. Less manufacturing cost per unit.

Limitations

Besides having several advantages, mass production also suffers from few limitations

1. If one machine stops functioning, then the entire or complete or whole production line would be halt.
2. Alteration in the product design would drastically alter the line layout.
3. Greater investment in production facilities.
4. In mass production, the cycle time is ascertained with the help of the slowest operation.

1.5.5 Continuous Process

Q33. Describe briefly about Continuous Process.

(OR)

What are the advantages and dis-advantages of continous process.

Ans :

Continuous production system deals with continuous physical flow of materials. It is used when the product has fast consumption rate and has continuous demand.

Examples

Petrol, Chemicals, Electricity etc.

Characteristics

The following are the characteristics of continuous production system.

1. In the continuous production system, the products passes through the same process.
2. The handling of material is done automatically in continuous production system.
3. In the continuous production system, the layout of the plant is designed on the basis of the production requirements.
4. Sophisticated control methods are used for measuring and controlling the inputs and outputs.
5. Proper maintenance of plants and effective control of quality are the prerequisites of continuous production system.

Advantages

The following are the advantages of continous production system.

1. In continuous production system, the production planning and control is simple when compared to job or batch production.
2. It makes use of specialized machines and procedures for standardizing the items in large quantities.
3. In the continuous production system, if the management takes the decision for discontinuing a particular line, then same machinery can be used for manufacturing other article.
4. The material handling is minimized in continuous production system.
5. The machine resetting involves very less time in continuous production system.
6. There is balanced flow of work in the continuous production system.
7. Continuous production system helps in providing lowest production cost per unit.

Disadvantages

The following are the disadvantages of continuous production system,

1. The effective working of continuous production systems depends on effective plant maintenance and effective quality control.
2. In continuous production system, the managers has to spend significant efforts for the planning before starting the production.
3. As continuous production system makes use of specialized machines, the amount of investment spent on these machines are very high.

Short Question and Answers

1. Define process design.

Ans :

Meaning

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 organization's resources to provide something of value. No product can be made and no service can be provided without a process and no process can exist without a product or service.

Process design is concerned with the overall sequences of operations required to achieve tfff design specifications of the product. It specifies the type of work stations that are to be used, the machines and equipments necessary to carry out the processes to produce the product. The choice of process technology (i.e., manual, mechanized or automated technology) and the process design is related to product design because the manufacturing processes must be capable of achieving the product quality (accuracy, tolerance etc.) specified in the product design and also the product must be designed for productivity.

2. Product life cycle.

Ans :

Meaning

1. Introduction Stage

In the introduction stage, the firm seeks to build product awareness and develop a market for the product.

2. Growth Stage

In the growth stage, the firm seeks to build brand preference and increase market share.

- **Product** quality is maintained and additional features and support services may be added.
- **Pricing** is maintained as the firm enjoys increasing demand with little competition.
- **Distribution** channels are added as demand increases and customers accept the product.
- **Promotion** is aimed at a broader audience.

3. Maturity Stage

At maturity, the strong growth in sales diminishes. Competition may appear with similar products. The primary objective at this point is to defend market share while maximizing profit.

4. Decline Stage

As sales decline, the firm has several options:

- Maintain the product, possibly rejuvenating it by adding new features and finding new uses.
- Harvest the product - reduce costs and continue to offer it, possibly to a loyal niche segment.
- Discontinue the product, liquidating remaining inventory or selling it to another firm that is willing to continue the product.

3. Process life cycle.

Ans :

1. Job Shop Technology

It is used in the start up stage of process life cycle as it is suitable for producing small batches of variety of products wherein each product is designed conventionally and ultimately needs its unique set of processing steps which are to be carried out through out the complete production process.

2. Batch Technology

It is used in second stage of process life cycle. It is used in rapid growth stage because batch facilities are best suitable in situations wherein wide range of products are demanded again and again and in large volumes. Batch technology is suitable to produce a wide range of products in wide variety of volumes.

3. Assembly Line Technology

It is used in the maturation stage as it helps in producing limited range of standardized products in high volume.

At this stage of process life cycle, product designs are comparatively stable and advanced equipment, experienced human skills and management systems are developed and focused upon the limited range of products and volumes.

4. Continuous Flow Technology

It is used when product turns into a commodity in process life cycle. In this stage, the products and materials are produced in continuous and endless flow manner. In this stage, products become highly standardized with the help of continuous flow technology which provides a high volume continuous operation with capital intensive specialized automation.

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4. Define Job Process.

Ans :

Meaning

The job shop production system deals with producing the products for fulfilling the customer needs or requirements. In this system, all the orders need different processes and different sequences of technological order.

Characteristics

The different characteristics of job-shop production system are as follows,

1. The job shop production system helps in producing several different jobs in small batches.
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3. The product which is manufactured in job shop production system is costly and non-standardized. Example: Electric power plant, dams construction, machine shop, sheet metal etc.
4. Job shop production system assembles equipments and machines at one place for huge objects.
5. In the job shop production system, general purpose equipments are used which helps in producing various jobs by using the same machinery.

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5. Define production and operation management.

Ans :

Introduction

Production and Operations Management (POM) refers to the design, operation and enhancement of transformation process in which different inputs are converted into required outputs of products / services.

Today, the term 'operations management' is being used in place of 'Production and Operations Management'. The is because the production function which is related to manufacturing firms is now incorporated is operations. Operations management not only deals with manufacturing organizations but also the service organizations.

E.S. Buffa defines production management as follows:

'Production management deals with decision-making related to production processes so that the resulting goods or services are produced according to specifications, in the amount and by the schedule demanded and out of minimum cost'.

(i) Production

Production is a scientific process which involves transformation of raw material (input) into desired product or service (output) by adding economic value.

(ii) Operations Management

Operations management is the process which combines and transforms various resources used in the Production/Operations sub system of the organization into value added products /services in a controlled manner as per the policies of the organization.

6. Define the term production, planning and control.

Ans :

Meaning

Production consists of a sequence of operations that transform materials from a given form to a desired form (products). The highest efficiency in production is obtained by manufacturing the required quantity of products, of the required quality, at the required time, by the best and cheapest method. To achieve this objective, production management employs production planning and control function which is a management tool that coordinates all manufacturing activities.

7. Objectives of PPC.

Ans :

1. To deliver quality goods in required quantities to the customer in the required delivery schedule to achieve maximum customer satisfaction and minimum possible cost.
2. To ensure maximum utilization of all resources.
3. To ensure production of quality products.
4. To minimize the product through-put time or production/manufacturing cycle time.
5. To maintain optimum inventory levels.
6. To maintain flexibility in manufacturing operations.
7. To co-ordinate between labour and machines and various supporting departments
8. To plan for plant capacities for future requirements.
9. To remove bottle-necks at all stages of production and to solve problems related to production.
10. To ensure effective cost reduction and cost control.
11. To prepare production schedules and ensure that promised delivery dates are met.
12. To produce effective results for least total cost.

8. What are the principles of PPC?

Ans :

1. Type of production determines the kind of production planning the and control system needed.
2. Number of parts involved in the product affect 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'.

9. Explain the limitations of PPC.

Ans :

(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.

10. Define Project Process.

Ans :

Meaning

The project process is featured by high level of customisation of job, greater scope for project and the necessity of the substantial resources for the project completion.

Example

Construction of dams, factories, hospitals, development of new products and so on.

The projects are usually sophisticated in nature and involves greaters time for completing and include greater number of difficult activities.

Features

The various features of project are,

1. A project has both the start and the end points. It is a separate entity.
2. Project is a non-repetitive task and not a permanent entity.
3. These tasks can be broken into recognized activities which need resources and times for their implementation.
4. It needs to be completed on a specified date.
5. The objectives and the output are clear and definite.
6. They are complex in nature and involve a time period of at least 2 to 3 years or 6 months or few projects may also have time duration of 10 years.

11. What are the advantages and dis- advantages of job process.

Ans :

Advantages

The following are the advantages of job-shop-production,

1. The job shop production system requires small amount of investment in equipments and machinery.
2. It is flexible in nature.
3. In the job shop system, a mistake or defect in one operation, does not interrupts the whole process.
4. It involves less managerial problems.
5. It can be started easily.
6. The risk involved is less, and the chances of failure are also less.

Disadvantages

Job shop system has the following dis-advantages,

1. The production system of job shoo system is very complicated.
2. It needs an elaborate schedule of activities.
3. The job shop system faces difficulty in loading the machines.
4. It requires high inventories
5. The cost of material handling involved in job shop system is high.

12. Continuous Process.

Ans :

Continuous production system deals with continuous physical flow of materials. It is used when the product has fast consumption rate and has continuous demand.

Examples

Petrol, Chemicals, Electricity etc.

Characteristics

The following are the characteristics of continuous production system.

1. In the continuous production system, the products passes through the same process.
2. The handling of material is done automatically in continuous production system.
3. In the continuous production system, the layout of the plant is designed on the basis of the production requirements.
4. Sophisticated control methods are used for measuring and controlling the inputs and outputs.
5. Proper maintenance of plants and effective control of quality are the prerequisites of continuous production system.

Choose the Correct Answers

1. The long term decisions included in the scope of operations management are, [d]

   (a) Facility location (b) Plant layout design

   (c) Capacity planning (d) All the above

2. The primary objectives of production department are, [c]

   (a) Cost reduction (b) Quality improvement

   (c) Both (a) and (b) (d) Material management

3. The process applied for producing average volume of moderate variety of goods and services is, [a]

   (a) Batch process (b) Job shop process

   (c) Project process (d) Continuous process

4. The major process decisions considered by production/operations manager are, [d]

   (a) Capital intensity (b) Customer involvement

   (c) Resource flexibility (d) All the above

5. It is _____ necessary to observe the performance of transformation process. [b]

   (a) Transformation mechanism (b) Feedback mechanism

   (c) Performance mechanism (d) None of the above

6. The development of operations involves, [d]

   (a) Business strategy (b) Corporate mission

   (c) Competitive priorities (d) All the above

7. The different techniques of PPC are, [d]

   (a) Aggregate planning (b) Make or Buy decisions

   (c) Process layout (d) Both (a) and (b)

8. _____ involves the important decision about how to make the optimum utilization of the resources. [a]

   (a) Capacity planning (b) Aggregate planning

   (c) Production planning (d) Material planning

9. The process in which two pieces to be joined are overlapped and placed between two pointed electrodes _____. [a]

(a) Spot welding (b) Resistance welding

(c) Projection welding (d) Seam welding

10. During solidification of metal casting, compensation for solid contraction is, [d]

(a) Made by providing chills (b) Provided by over size pattern

(c) Achieved by properly placed riser (d) Obtained by promoting directional solidifications

Fill in the Blanks

1. _____ is the branch of management which studies all processes and systems undertaken to convert inputs into value added outputs.
2. _____ is flexible and provide a fast response to changing market trends, requirement of customers and to the actions of competitors.
3. When low volume of high variety goods are produced, _____ process is used.
4. Semi continuous process is also known as _____.
5. _____ refers to the active participation of customers in the production process.
6. _____ is an evaluation technique which involves charts used for analyzing and controlling product and services to satisfy delivery schedules.
7. The first phase of PPC in which firms are involved in forecasting the appropriate actions through which stated objectives can be achieved is _____.
8. _____ is defined as an orientation and harmonization of the organizations materials and facilities towards achievement of goals.
9. The process of joining two materials with the help of heat or pressure or by some other means is known as _____.
10. The products have fine grain structure with high density in _____ casting.

ANSWERS

1. Operation management
2. Agile manufacturing
3. Job shop
4. Repetitive process
5. Customer involvement
6. Line of Balance
7. Planning phase
8. Production planning and control
9. Centrifugal
10. Non conventional machining.

UNIT II

PLANT MANAGEMENT AND WORK STUDY :

Capacity Planning, factory location, plant layout – types of layout. Sequencing of Operations: n-Jobs with one, two and three facilities. Work Study: The concept and various techniques of methods analysis and work measurement.

2.1 Capacity Planning

Q1. Define Capacity. Explain different types of Capacity.

Ans :

Meaning

Capacity is amount of output a system is capable of achieving over a specific period of time. Capacity of a plant is the ability of the plant to meet the demand in terms of products or services offered by the plant. Capacity represents the maximum rate of output of a facility. Capacity affects the company's ability to meet market demand, the types of markets it can enter and its ability to compete in those markets.

Types

(i) Production capacity

Is the maximum rate of production (or output) of an organization,, for example, 100 cars per day or 200 refrigerators per day etc. But several factors underlying the concept of capacity makes its understanding and use somewhat complex. Variation in employee absenteeism, equipment breakdowns, vacations, holidays, delays in material procurement/delivery, work schedules (e.g., 5 days-week work), working hours (hours/ shift), use of overtime, temporary workers, outsourcing etc., must be taken into account when estimating the production capacity. Hence, the capacity is estimated interms of sustainable practical capacity which is defined as "the greatest level of output that a plant can maintain within the frame work of a realistic work schedule, taking into account of normal downtime, and assuming sufficient availability of inputs to operate machinery and equipment in place".

(ii) Design capacity

Design capacity refers to the maximum output that can possibly be attained. It is the maximum rate of output achieved under ideal conditions.

(iii) Effective capacity

Effective capacity is the maximum possible output given a product- mix, scheduling difficulties, machine maintenance, quality factors, absenteeism etc.

Effective capacity is usually less than design capacity (it can not exceed design capacity) because of capacity losses due to realities such as product-mix changes, need for periodic preventive maintenance of equipment, problems in scheduling and balancing operations, coffee breaks, lunch breaks and so on.

Actual output can be lesser than effective capacity because of machine breakdown, absenteeism, shortage of materials and quality problems.

(iv) Maximum capacity

Also known as peak capacity, it is the maximum output that a facility can achieve under ideal conditions. Where capacity is measured relative to equipment alone, it is known as rated capacity.

(v) Measures of capacity

Different measures of capacity are applicable in different situations. For example, capacity

of an automobile plant can be measured in terms of the number of automobiles produced per unit of time (shift, day, week or month whereas, capacity of a hospital is measured in terms of the number of patients the can be treated per day. Therefore, capacity of a facility can be either measured in terms of outputs or in terms of inputs.

Q2. What do you understand by Capacity Planning. Discuss the classification of Capacity Planning.

Ans :

Meaning

Capacity planning is the task of determining the long-and short-term capacity needs of an organization and then determining how these needs will be satisfied.

Types

(i) Long-term capacity planning

Top management may have the following strategies to cope up with major changes in products and services that it can provide to customers in the long run which will have significant impact on the capacity. The major changes will altogether revise the demand and resource requirements. These are:

- Develop new product lines
- Expand existing facilities
- Construct or phase out production plants

Technological obsolescence may force some industries to use phase-in strategy for introducing the next model of the same product or service to retain and/or improve its market segment. The phase-in strategy is nothing but the planning for the next model even when the present model is moving well. Especially, in electronics industry, any company should do continuous research and development to improve the operational features of the product through advanced technology so that the company will be in a position to bring out products into the market with the latest technology without any time lag.

At the same time, all the products will not have continued demand for ever. Moreover, continuing the production of some products will be uneconomical over a period of time. This will force a company to diversify and/or phase out some of the existing products. Phasing out of a product should be done over a period of time properly by taking the re-employment features into account.

(ii) Short-term capacity planning

In short-term planning horizon, capacity decisions are taken by considering the fluctuations in demand caused by seasonal and economic factors. The purpose of short-term capacity planning is to respond to variations in demand during the short-term planning horizon. Strategies like, overtime, subcontracting, hiring, firing, etc., can be used to cope up with the fluctuations in demand.

Q3. Explain the factors determining capacity planning.

Ans :

Many decisions about design of the production system and operation of the production item may have an impact on capacity.

1. Facilities factors

The key factor is the design of facilities including size and provisions. 'Nurture expansion. Other locational factors such as costs of transportation, distance to market, supply of suitable labour, energy sources etc., are also important. In addition plant layout, 'up layout, utilities such as heating, lighting, ventilation etc., may affect labour efficiency and there by effective capacity.

2. Product/service factors

Uniformity of products/services (e.g., a product line rather than a product-mix) provides opportunities for standardization of methods and materials, which leads to greater effective capacity.

3. Process factors

The quantity and quality capability of a process or equipment increase he rate of output and hence the effective capacity.

4. Human resource factors

Human factors that affect potential and actual output are job design,

(i) Job design

(ii) Variety of activities involved,

(iii) Training, skill and experience required to perform a job,

(iv) Employer motivation,

(v) Employee absenteeism,

(vi) Employee turn-over.

5. Operational factors

Differences in capabilities of alternative equipments and differences job requirements may create scheduling problems. Other factors such as inventory decisions, ate deliveries by suppliers, quality of purchased materials and parts, inspection and quality control procedures may also have an impact on effective capacity.

6. External factors

These relate to product standards, safety regulations, labour activities, pollution control standards etc., which may often reduce effective capacity.

Q4. Enumerate the steps involved in capacity planning.

Ans :

The process involved in capacity planning is as follows:

1. Demand forecasting

Capacity planning starts with the setting of up of a business plan which sets out the types of goods or services to be produced. The Manager has to take a long range forecast of demand in order to determine the resources needed to produce and offer specified goods and services. Market trend changes, competitor's role and technological changes have to be carefully examined.

2. Capacity decisions

The demand forecasting of goods and services then must be translated in to a measure of capacity needed. On the basis of forecasting of demand for products, organization will be able to determine the various resources needed for producing such goods.

3. Facilities planning

Capacity decisions automatically lead to the setting up of necessary facilities in order to produce goods and services as determined the previous steps. Facility planning can be done either by the expansion or contraction of existing facilities or by setting up of additional new facilities.

4. Decisions and implementation

Finally, alternative resource requirements plan should be properly evaluated. The feasibility of plans along with its economic impact needs to be analysed. Detailed study of economic impact of resource requirements is essential to make the capacity planning a reality.

Q5. Explain the importance of capacity planning.

Ans :

1. Capacity decisions have an impact on the ability of the organization to meet future demands for products and Services.
2. Capacity decisions affect operating costs. It should be seen that capacity and demand requirements will be matched, which will tend to minimize operating costs. In practice, this is not always achieved because actual demand either differs from expected demand or tends to vary. In such cases, a decision might be made to attempt to balance the costs of over and under capacity.
3. Capacity is usually a major determinant of initial cost.
4. Capacity decisions often involve long-term commitment of funds.
5. Capacity decisions can affect competitiveness.
6. Capacity planning reduces the complexity in manufacturing operation.

Q6. Discuss the Principles of capacity planning.

Ans :

The following are the principles for planning for the adequate capacity resources within an infrastructure.

1. Agree on a common definition of capacity planning

Capacity planning means different things to different people. Agreeing on a common, formal definition of the process is essential in designing and implementing an effective capacity planning program. Proper care should be taken in defining various concepts of capacity planning.

2. Select a capacity planning process owner

The next step is to select a suitable qualified individual to serve as the process owner. The person will be responsible for designing, implementing and maintaining the process and will be empowered to negotiate and delegate with developers and other support groups.

3. Identify the key resources to be measured

Once the process is selected, the next task is to identify the infrastructure resources to be measured.

4. Compare current utilization to maximum capacities

This principle aims to determine how much excess capacity is available for selected components. The utilization or performance of each component measured should be compared to the maximum usable capacity.

2.2 FACTORY LOCATION

Q7. What is meant by Factory / Plant Location ?

Ans : **(July.-19, Dec.-18, Imp.)**

A plant is a place, where men, materials, money, machinery and equipment, etc., are brought together for manufacturing product. Plant location decisions are crucial because they commit organizations to long lasting financial, employment, a distribution patterns. As such, they deserve the careful attention of finance, personnel, marketing and other managers, as well as that of the operations mangers who manage the facilities.

Plant location is not a static decision that can be made and forgotten. Plant layout or facility layout choices follow the location decisions. They influence the type of equipment and level of technology employed, the flow of work and design of jobs, inventory levels, and other operating characteristics of the firm. Layout can be changed more easily than locations. However, they represent more of a continuing concern. In addition, they fall more directly within the responsibility of operations manager because they deal with the physical arrangement of productive facilities.

Q8. What are the factors influencing selection plant location ?

(OR)

Discuss the factors which determines the location of plant.

Ans : **(Imp.)**

Decision regarding location requires a careful balancing of several factors. Some of them are more important and are known as primary factors, while the less important one are known as secondary factors. Sometimes in real problem secondary factors may show greater influence in selecting the locations.

(A) Primary Factors

1. **Availability of raw material :** In order to minimise the transport cost of raw material to the industrial plant, the nature of raw material is of great importance. A good deal of economy in transport costs can be achieved if the industries, which use weight-losing materials, are located nearer to the source of raw materials. In case industries uses ubiquitous material, the material transport cost factor do not influence the location much.

2. **Nearness of Market for the Finished Product :** Industries, using pure raw materials are generally located nearer to the market for the product produced. By locating the unit nearer to the market, the transportation cost finished goods will be minimum. In addition to this factor, the chances of finished goods getting damaged or spoiled during

transport can be reduced. As the industry is nearer to the market, it can catch a big share of the market and can render quick service to the customers.

3. **Availability of Fuel and Power :** The problem of fuel and power can also be soled with reference to the nature of raw materials. Industries, which used coal as the source of power or their industries, are located nearer to the local bed. Because coal loses, substantial weight during processes. Now a day as the electricity is generally used as power source, this factor is losing its importance.

4. **Transport Facilities :** A lot of money is spent both in transporting the raw material and the finished goods. Depending on the size of raw material or finished good, a suitable method of transportation like roads, rail, water or air is selected and accordingly the plant location is decided. The point to be considered here is that the cost of transport must be kept at a minimum. This is because, the movement of material will simply add to the cost and nothing to the use/economic value of the material or product.

5. **Availability of Labour :** Another important factor influencing the location of industries is availability of suitable and adequate number of labour at a reasonable labour wages. This particularly true in case of plants like, tobacco companies and tea estates, etc. However, labour will not attract industry by itself as it is mobile. Any labour intensive companies have to select a location nearer to the source of labour.

6. **Availability of Water :** In case water is used for processing, as in paper and chemical industries, and is also required for drinking and sanitary purposes. Depending on the nature of plant, water should be in adequate quantity and should be of desired quality.

B) Secondary Factors

1. **Solid and Climate :** The question of soil and climate is really an influencing factor for an units processing agricultural products like tea, coffee etc. With the development in the field of heating, ventilating and air-conditioning climate of the region is not a problem these days.

2. **Industrial Atmosphere :** The industrial atmosphere cannot be measured in tangible terms, but it has a very important advantage in selecting a location for a plant. Industrial atmosphere may said to exist where people living at a place think instinctively of industry and learn the intricacies of machines without much effort. This is an added advantage for the growth of industries in a particular area.

3. **Financial and Other Aids :** The plant should be located in an area where financial institutions are available to get a part of capital as loan and getting working capital and for other financial aids.

4. **Availability of Facilities like Housing, Schools, Hospitals and Recreation Clubs :** The site should be nearer to infrastructure facilities, so that the labour will have housing facilities at a reasonable cost and they will take advantage of educational institutions to educate their children. For health problems, they can use hospitals. They can relax during off periods in recreation clubs. All the above-said facilities will help in motivating the labour to stick to the job, i.e., labour turnover will be at low rate.

5. **Momentum of an Early Start :** There are number of places where, to begin with, only one or two factories were started. With the passage of time these places gained importance and attract industries. As these number of industrial units increase, certain facilities are

developed in that area. Some of the facilities are banking facility; maintenance units and other related units will come up. With these, availability of skilled labour also increases.

6. **Special Advantages of the Place :** Sometime certain facilities are offered by the state, in case the particular region is selected. Facilities like providing subsidies, tax holidays etc. In this ways state tries to develop the under-developed areas.

7. **Personal Factors :** Sometimes, promoters, irrespective of economic factors, prefer to start their unit in their place of origin to develop the area and help the fellow community. A good example for this is Ford Company at Detroit.

8. **Historical/Actors :** Factors like personal fancies of entrepreneurs or historical incidents may in many cases lead to the development of a place as the centre of an industry. Example is development of Kanpur as textile industry centre.

9. **Political Stability :** The lack of political stability in a state makes for uncertainty in the attitude of State Governments to industries. In locating industries plan, it must be seen as to whether the State has a record of political and economic stability.

2.3 PLANT LAYOUT

Q9. Define the term plant layout. What are the objectives of plant layout?

Ans : **(Dec.-19)**

Meaning

A plant layout refers to the arrangement of machinery, equipment and other industria facilities such as receiving and shipping departments, tool rooms, maintenance rooms and employee amenities for the purpose of achieving the quickest and smoothest production a- the least cost. The subject of plant layout not only covers the initial layout of machines and other facilities but encompasses improvement in, (or) revisions of, the existing layout in the light of subsequent developments in the methods of production. In other words, a plat layout is a floor plan for determining and arranging the desired machinery and equipment of a plant, whether established or contemplated, in the one best place to permit the quickes flow of material at the lowest cost and with the least amount of handling in processing the product from the receipt of the raw materials to the shipment of the finished products.

Definitions

(i) According to Knowles "Planning and arranging manufacturing machinery, equipment, and services for the firs' time in completely new plants;

(ii) According to Thomson The improvements in layouts already in use in order to introduce new methods an improvements in manufacturing procedures.'

Objectives

Any of the following objectives might be achieved through a good layout:

- Provide enough production capacity
- Reduce material handling costs
- Reduce congestion that impedes the movement of people or material
- Reduce hazards to personnel
- Utilize labour efficiently
- Increase employee morale
- Reduce accidents
- Utilize available space efficiently and effectively
- Provide for volume and product flexibility
- Provide ease of supervision
- Facilitate co-ordination and face-to-face communication where appropriate
- Provide for employee safety and health
- Allow ease of maintenance
- Allow high machine/equipment utilization
- Improve productivity.

Q10. Discuss the factors influencing the plant layout.

Ans :

1. Materials

When it is said that materials influence plant layout, what is meant is that e is a need to provide for the storage and movement of raw materials in a plant until they are converted into finished products. Every factory should buy raw materials economically men they are available; they should be stored properly and moved through production centres efficiently for manual or mechanical operations or chemical processing. The storage and movement of raw materials require properly placed storage rooms and materials movement (or) Handling equipment. These involve initial investment and recurring costs. The type and :e of storage, as also the type of materials equipment cranes, trolleys and pipelines depend upon.

(i) The type of raw materials used, i.e., whether the raw materials are liquid or solid, light or heavy, small or large; and

(ii) The availability or scarcity of materials even when this is affected by seasonal variations and market conditions.

2. Product

A layout is designed with the ultimate purpose of producing a product. The type of product - that is, whether the product is heavy or light, big or small, liquid (or) solid - and its position in relation to the plant location influence the layout. In a majority of cases, the product moves from work station to work station. In some cases, as in the manufacture of locomotives and in ship-building, the product is stationary; but machinery and men are moved to the product. Thus, the position of the product in relation to the other factors of production deserves consideration in planning a layout. In the same way, the size of the product should be considered in planning the layout of a plant. The requirements of a layout meant for a heavy product are different from the requirements of that for a light product. Again, the layout requirements for assembling a watch are different from those for the assembly of an aeroplane. The manufacture of certain products involves wet operations, as in leather tanning or textile dyeing.

3. Worker

The layout designer should also consider the type, position and requirement: of employees. If women workers are employed, the layout must be planned after keeping ir mind their particular requirements. The position of employees, that is, whether they remain stationary or moving, also influences the layout.

4. Machinery

The type of product, the volume of its production, the type of process and management policy determines the size and type of the machinery to be installed which, in turn, influences the plant layout. Production is the combination and manipulation of men materials and machines. These elements may be combined in various ratios and in various ways in the course of the production activity. The ratio in which these elements are used depends on their relative costs and on the production processes selected. Before laying out of a plant, it is necessary to determine which of these elements are to be stationary or fixed as to location in the plant and which will be mobile during the process of production. Various alternatives are available in determining which factor to move :

(i) To move the product and the workers from work station to work station.

(ii) To move the product from work station to work station, keeping the machines and workers stationary.

(iii) To move the worker and the machine to the product, which is held at the location. The layout (or) arrangement of machines should be planned to suit the alternate used in a plant.

5. Location

The site selected for the location of a plant influences its layout in more than one way. First, the size and the terrain of the site determine the type of building which, in turn, influences the layout. Second, the location of the plant determines the mode of transportation, depending upon the distances from the source of raw materials and market to “e plant. In some cases, railroads are used, in some others trucks are pressed into service. In a few cases, water loading and unloading facilities are required. The layout plan should provide for the

exact type of transportation required. Third, a plant location may be determined in part by the fuel requirements of the concern. The plant layout must provide for. the storage this fuel, whether it be coal, oil (or) gas. Also, the layout must consider the requirements of power generation. Fourth, the demand for future expansion influences the plant layout. If a large site is selected, expansion may be effected by adding one more wing to the existing single-story construction. If an urban site is selected, expansion may be effected by adding one stories to the present structures.

6. Managerial Policies

Management policies significantly influence plant layout. The following are such managerial policies:

(a) The volume of production and provision for expansion.

(b) The extent of automation.

(c) Making or buying a particular component.

(d) Desire for rapid delivery of goods to customers.

(e) Purchasing policy.

(f) Personnel policies.

Q11. What are the principles of plant layout?

Ans :

(i) Principle of Minimum Travel

Men and materials should travel the shortest distance between operations so as to avoid waste of labour and time and minimise the cost of materials handling.

(ii) Principle of Sequence

Machinery and operations should be arranged in a sequential order. This principle is best achieved in product layout, and efforts should be made to have it adopted in the process layout.

(iii) Principle of Usage

Every foot of available space should be effectively utilized. This principle should receive top consideration in towns and cities where land is costly.

(iv) Principle of Compactness

There should be a harmonious fusion of all the relevant factors so that the final layout looks well integrated and compact.

(v) Principle of Safety and Satisfaction

The layout should contain built in provisions for safety for the workmen. It should also be planned on the basis of the comfort and convenience of the workmen so that they feel satisfied.

(vi) Principle of Flexibility

The layout should permit revisions with the least difficulty and at minimum cost.

(vii) Principle of Minimum Investment

The layout should result in savings in fixed capita investment, not by avoiding installation of the necessary facilities but by an intensive use of available facilities.

2.3.1 Types of Layout

Q12. What are the different types of plant layout ? Explain in detail about product layout.

Ans : **(Imp.)**

The following are the different types of plant layout

(i) Product Layout

(ii) Process Layout

(iii) Fixed position Layout

(iv) Cellular Manufacturing Layout

(v) Combined Layout

(i) Product Layout

Product layout is used when machines and auxiliary services are located according to the processing sequence of the product. The product layout is selected when the volume of production of a product is high such that a separate production line to manufacture it can be justified. In a strict product layout, machines are not shared by different products. Therefore the production volume must be sufficient to achieve satisfactory utilization of the equipment.

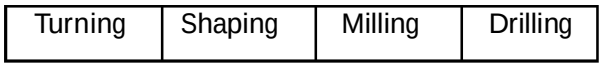


Fig.: Product layout.

Advantages

(i) The flow of product will be smooth and logical in flow lines.

(ii) In-process inventory is less.

(iii) Throughput time is less.

(iv) Material handling cost is minimum.

(v) Operators need not be skilled.

(vi) Simple production planning and control systems are possible.

(vii) Less space is occupied by work in transit and for temporary storage.

Limitations

(i) A breakdown of one machine in a product line may cause stoppages of machines in the downstream of the line.

(ii) A change in product design may require major alterations in the layout.

(iii) The line output is decided by the bottleneck machine.

(iv) Comparatively high investment in equipments is required.

Q13. What is Process Layout ? Explain the functions, advantages and disadvantages of process layout.

Ans :

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

For example, machines performing drilling operations are fixed in the drilling department machines performing casting operations are grouped in the casting department; and so on. In this way, there would be a heating department, a painting department, a machining department and the like, where similar machines are installed in the plants which follow the process layout. The process arrangement is signified by the grouping together of like machines based upon their operational characteristics.

A quantity of raw material is issued to a machine which performs first operation. This machine may be situated anywhere in the factory. For the next operation, a different machine may be required, which may be situated in another part of the factory. The material should be transported to this other machine for treatment. Thus, material would move long distances and along crisscrossing paths. At one stage, the material may be taken to a separate building, say, for heat treatment, and then brought back for grinding. If machines in one department are engaged, the partly finished product awaiting operations may be taken to the store and after reissued for production. Partly finished goods would be waiting for treatment in every department, like commuters waiting for buses in a city.

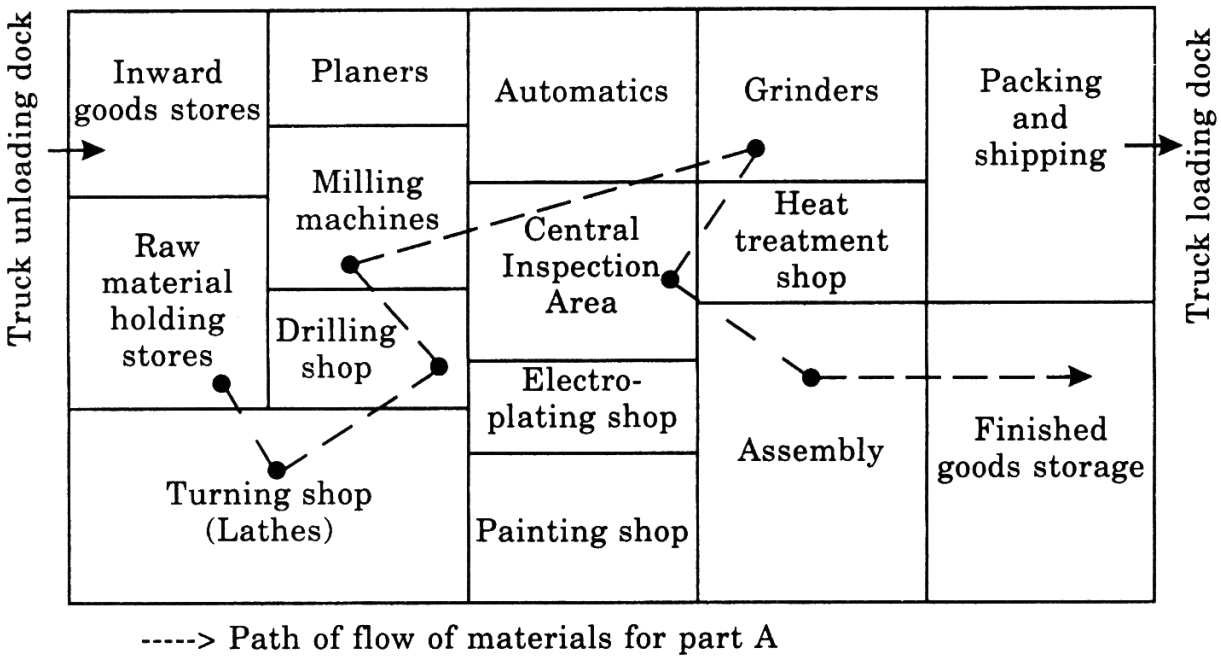


Fig.: Process Layout or Functional Layout or Job Shop Layout

Advantages

- Reduced investment of machines as they are general purpose machines.
- Greater flexibility in the production.
- Better and more efficient supervision is possible through specialization.
- There is greater scope for expansion as the capacities of different lines can be easily increased.
- This type of layout results in better utilization of men and machines.
- It is easier to handle breakdown of equipment by transferring work to another machine or station.
- There is full utilization of equipment.
- The investment of equipment would be comparatively lower.
- There is greater incentive to individual worker to increase his performance.

Disadvantages

- There is difficulty in the movement of materials. Mechanical devices for handling materials cannot be conveniently used.
- This type of layout requires more floor space.
- There is difficulty in production control.
- Production time is more as work-in-progress has to travel from place to place in search of machines.
- There is accumulation of work-in-progress at different places.

Q14. Compare and contrast product layout and process layout.

Ans :

S.No.	Product Layout	S.No.	Process Layout
1.	Mechanization 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.

Q15. What is Fixed position Layout? Explain the advantages of Fixed position Layout.

Ans :

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. It also called the fixed location layout, this type is followed in the manufacture of bulky and heavy products, such as locomotives, ships, boilers, air craft and generators. The construction of a building requires a fixed location layout because men, cement, sand, bricks, steel, wood and others, are taken to the site of the construction. This is equally true of a brick kiln. Another example is that of a hospital, where doctors and nurses (workers) and medicines and other paraphernalia (materials) are taken to the patient (product).

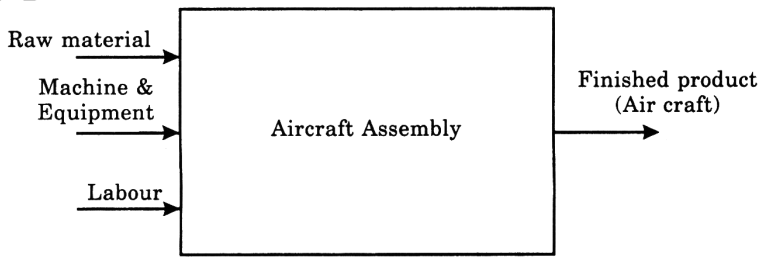


Fig.: Fixed Position Layout (or) Static Layout

The advantages of a fixed position layout are:

(i) Men and machines can be used for a wide variety of operations producing different products.

(ii) The investment on layout is very small.

(iii) The worker identifies himself with the product and takes pride in it when the work is complete.

(iv) The high cost of, and difficulty in transporting a bulky product are avoided.

Q16. What is Cellular Manufacturing Layout? Explain the advantages and disadvantages of Cellular Manufacturing Layout.

Ans :

In cellular manufacturing (CM), machines are grouped into cells, and the cells fusion somewhat like a product layout within a larger shop or process layouts. Is an illustration of CM layout. Each cell in the CM layout is formed to produce a single parts family a few parts, all with common characteristics, which usually means that they require the same machines and have similar machine settings.

The flow of parts with in cells, as shown in can take many forms. For example, in cells #1 and #2, the parts in the part family flow through the same machines in a product focused, line flow fashion. But in the cells #3 and #4, parts take different routes through the cells because of the differences between the designs of the two parts.

Advantages

- Cellular layouts are lower work-in-process inventories, reduced materials handling costs, shorter flow times in production, simplified production planning (materials and labour), increased operator responsibilities, improved visual control, and fewer tooling changes therefore facilitating quicker setups.
- Overall performance often increases by lowering production costs and improving on time delivery. Quality also tends to improve.

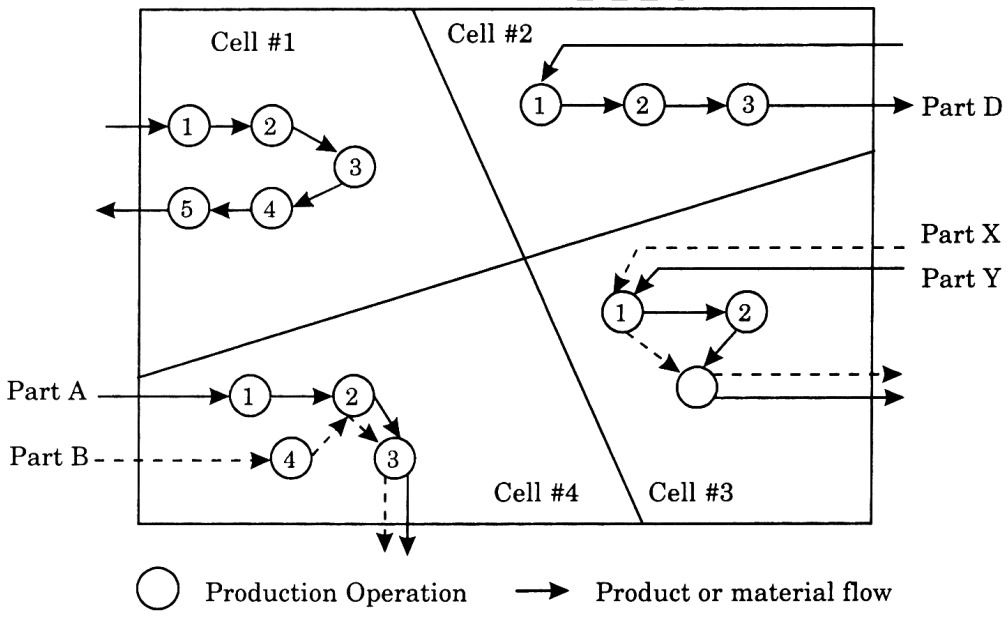


Fig.: Cellular Manufacturing Layout (or) Group Technology Layout

Disadvantages

- Reduced manufacturing flexibility and potentially increased machine-down time (since machines are contained to cells and may not be used all the time)
- Duplicate pieces of equipment may be needed so that parts need not be transported between cells.

Q17. Explain briefly about Combined Layout.

Ans :

The application of the principles of product layout, process layout (or) fixed location layout in their strict meanings is difficult to come across. A combination of the product and process layouts, with an emphasis on either, is noticed in most industrial establishments. Plants are never laid out in either pure form. It is possible to have both types of layout in an efficiently combined form if the products manufactured are somewhat similar and not complex.

In plants involving the fabrication of parts and assembly, fabrication tends to employ the process layout, while the assembly areas often employ the product layout. In soap manufacturing plants, the machinery manufacturing soap is arranged on the product-line principle but ancillary services, such as heating, the manufacturing of glycerine, the power house, the water treatment plant are arranged on a functional basis.

The departments in are arranged cording to the types of processes but the products flow through on a product layout.

To extend the logic of the combined layout, we may refer to the application of the fixed location principle in every industrial establishment.

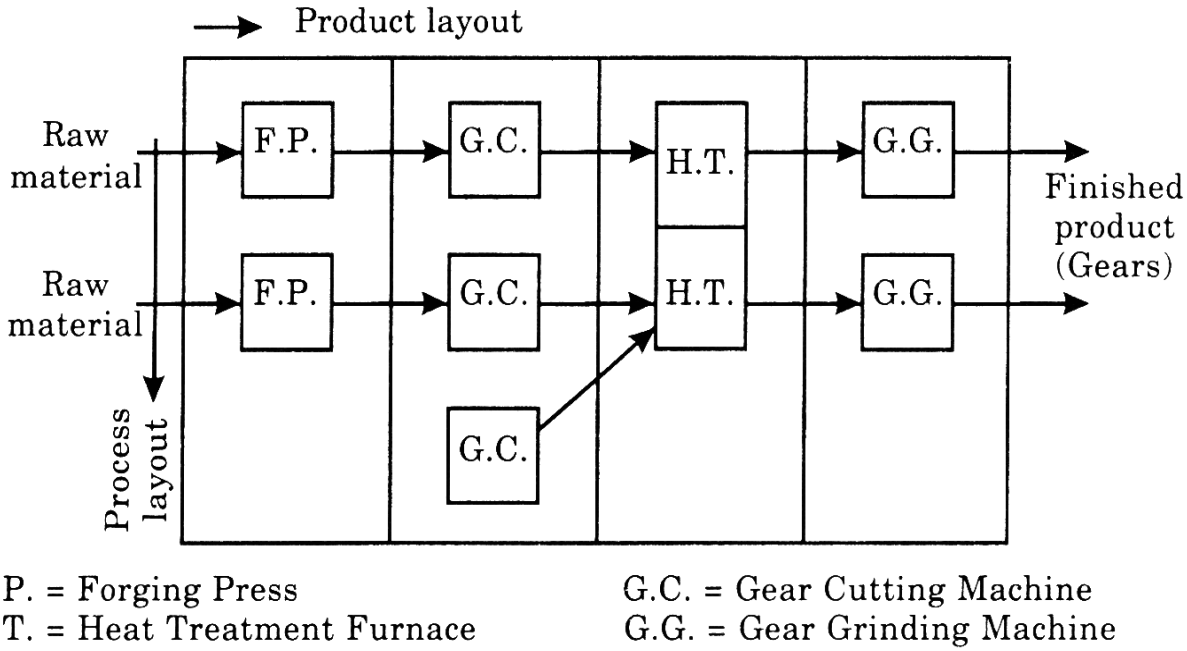


Fig.: Combination Layout or Hybrid Layout for Gear Manufacturing

In the final analysis, the combination that produces the desired volume of products at the least total cost is preferred. Marketing is concerned with maximising income, industrial engineering is concerned with minimising cost, and management is gambling that are is a sufficient difference in its favour.

2.4 Sequencing of Operations

Q18. Define the term Sequencing. Explain the basic terminology are used in Sequencing.

(OR)

What is sequencing of operations in jobs ?

Ans : **(Dec.-19)**

Meaning

Sequencing is the process by which different jobs waiting at their respective workstations can be processed based on their priority. Priority or importance of jobs can be determined by applying priority sequencing rules. According to the rules, the job which needs to be completed first is processed first followed by the processing of less prioritized jobs.

When there exists number of jobs in a queue for their processing, then an operations manager must provide an answer to a question as to which job should be processed first? This can be answered by determining the priority of all the jobs based on the priority rules.

The term "priority" denotes the processing sequence of jobs for different machines or work centres. Processing of highest priority job is done when the workcentre or the machine becomes free.

It is very difficult to select the right sequencing rule on the basis of a single criterion as there is no universally acceptable rule which can be valid under all the situations. The criteria used for selecting the right sequencing rule are as follows,

(i) Idle time

(ii) Average job lateness

(iii) Setup costs

(iv) Work in progress inventory cost

(v) Average flow time

(vi) Average number of jobs in the system

(vii) Average time to complete a job

(viii) Number or percent of late jobs.

Terms in Sequencing

Following are some of the terms used in performing the jobs on machines,

1. Number of Machines

Firms require various processes to complete the production of one unit of product. For example, to prepare a song, it must undergo a process of composing, singing, recording etc. Song is termed as a job whereas these processes are regarded as a number of machines.

2. Total Elapsed Time

It is the total time consumed for completing all jobs, starting from the first job to the last job and as well as idle time.

3. Processing Order

All the machines are arranged in an order to process the job for the completion of a given task.

4. No Passing Rule

Finns while processing cannot change the prescribed sequence. For instance, if the firm has ordered to process the job through machine *X* first and then to machine *Y,* then it has to process in the same order.

5. Processing Time

It is the total time consumed by the jobs on each machine.

6. Idle Time on a Machine

Idle time is the time in which no processing of jobs is done on the machines during the total elapsed time. Idle time is denoted by i and it is the difference between the end of job (i – 1) and start of job i.

Q19. Explain the principle assumptions made while dealing with sequencing problems.

Ans : **(July-19)**

(i) The processing time of each job on each machine duration needs to be predetermined and constant.

(ii) Any job started for processing must be completed at any cost.

(iii) A job must be operated only on the basis of predermined processing order.

(iv) On one machine only one job has to be processed.

(v) It takes very less time for the jobs to get transferred from one machine to another and hence the value the can be taken as equal to zero (or) neglible.

(vi) An operation must be completed before its succeeding operation starts.

(vii) The sequence of processing the machines once prescribed should be changed as per the rule.

(viii) Only one machine of each types is available.

2.4.1 Processing 'n' Jobs with one Facility/ Machine

Q20. How is sequencing done for 'n' jobs on one machine? Explain.

Ans : **(Dec.-19)**

The following are the rules of sequencing :

1. First Come First Served Rule (FCFS)

In FCFS rule, the jobs which arrives first at the facility or work centre will be served first. This rule is used mostly in the service centres like Banks, super markets, Insurance offices and others.

2. Shortest Process Time (SPT) Job First

In the SPT rule, the jobs having the shortest processing or operations time on the machine or at work centre will be assigned the highest priority. This rule helps in reducing the in-process inventory by giving less-priority to the jobs that requires high processing time.

3. Longest Processing Time (LPT) Job First

In this rule, the job having the longest processing time will be processed first on the machine when compared to the other jobs waiting in a queue.

4. Least Slack (LS) Job First

According to this sequencing rule, jobs which are having least slack time can be processed first. Where slack is obtained by deducting the processing time from the total time available for performing a job.

5. Earliest Due Date (EDD) Job First

In this rule, the sequencing and processing of jobs which are waiting in the queue at the work centre are done on the basis of their due dates. Highest priority is assigned to those jobs which have earliest due data.

6. Truncated Shortest Processing Time (TSPT) Job First

In this rule, the jobs are sequenced on the basis of the SPT rule. However, SPT rule is voilated, when the jobs are waiting in a queue for a long period of time than the specified time. Such jobs are given highest priority (than any other jobs).

7. Preferred Customer Order (PCO) Rule

In this rule, highest priority is given to those jobs that are mostly preferred by the customers.

8. Random Selection

This rule is usually not used and is only used when there is no other alternative available for selection.

9. COVERT (Cost Over Time) Rule

This rule is based on the results of cost over time ratio which is the ratio of expected delay cost to the processing time. In this ratio, higher priority is given to the job having the largest value of this ratio.

10. Least Change Over Cost

In this rule, the jobs are sequenced by examining the total cost incurred on changing the machines between the jobs.

PROBLEMS

1. Table shows the time remaining (number of days until due date) and the work remaining (number of day's work) for 5 jobs which were assigned the letters A to E as the arrived to the shop. Sequence these jobs by priority rules viz., (a) FCFS, (b) EDD, (c) LS, (d) SPT and (e) LPT.

Job	Number days until due date	Number of day's work remaining
A	8	7
B	3	4
C	7	5
D	9	2
E	6	6

Sol :

(a) FCFS (First come first served) : Since the jobs are assigned letters A to E as they arrived to the shop, the sequence according to FCFS priority rule is

A	B	C	D	E

(b) EDD (Early due date job first) rule : Taking into account the number of days until due date, the sequence of jobs as per EDD rules is

B	E	C	A	D
(3)	(6)	(7)	(8)	(9)

(c) L.S. (Least slack) rule also called as Minimum slack rule.

Calculation of slack :

Slack – (Number of days until due date) – (Number of days work remaining)

Job	Slack (Days)
A	8 – 7 = 1
B	3 – 4 = (–1)
C	7 – 5 = 2
D	9 – 2 = 7
E	6 – 6 = 0

Sequence :

B	E	A	C	D
(–1)	(0)	(10	(1)	(7)

(d) SPT (Shortest Processing Time job first) also referred as SOT (Shortest Operation time job First) rule (or) n MINPRT (Minimum Processing time job first) rule.

Sequence :

D	B	C	E	A
2	4	5	6	7

(e) LPT (Longest Processing time job first) also referred to as LOT (Longest operation time job first) rule.

Sequence :

A	E	C	B	D
7	6	5	4	2

2. The following jobs have to be shipped q week from now (weak has 5 working days)

Jobs	A	B	C	D	E	F
Number of day's work remaining	2	4	7	6	5	3

Sequence the jobs according to priority established by

(a) least stack rule (b) critical ratio rule.

Sol :

(a) Calculation of slack

Number of days until due is 5 days for all jobs

Job	Slack (Days)
A	5 – 2 = 1
B	5 – 4 = 1
C	5 – 7 = (– 2)
D	5 – 6 = (– 1)
E	5 – 5 = 0
F	5 – 3 = 2

Sequence :

C	D	E	B	F	A
–2	–1	0	1	2	3

(b) Calculation of Critical ratio :

$$\text{Critical ratio} = \frac{(\text{Due date}) - (\text{Date now})}{\text{Lead time remaining}}$$

$$= \frac{(DD) - (DN)}{LTR} = \frac{\text{Available time}}{\text{Operation time}}$$

Critical ratio for job A = 5/2 = 2.5

Critical ratio for job B = 5/4 = 1.25

Critical ratio for job C = 5/7 = 0.71

Critical ratio for job D = 5/6 = 0.83

Critical ratio for job E = 5/5 = 1.0

Critical ratio for job F = 5/3 = 1.67

Job having least critical ratio is given the first priority and son on.

Sequence :	C	D	E	B	F	A
Critical Ratio :	(0.71)	(0.83)	(1.0)	(1.25)	(1.67)	(2.5)

2.4.2 Processing 'n' jobs with two Facilities/Machine

Q21. How is sequencing done for n-jobs on two machines?

Ans : **(Dec.-19)**

Johnson's rule is a technique for minimizing make span for a group of jobs to the processed on two machines or at two work centres.

Conditions

a) Job time (including setup and processing) must be known and constant for each job at each work-centre.

b) Only two machines A and B are involved and all jobs must follow the same two-step work sequence i.e., AB.

c) All units in a job must be completed on machine A before the job moves to machines B.

d) Expected processing time on machine A is A_1, A_2, A_3.....A_n. On machine B is B_1, B_2, B_3.... B_n, of jobs "1, 2, 3, ... n".

Steps of Johnson's Rule

1. Select the job with the shortest processing time

	Processing time (Jobs)
Machine A	A_1, A_2, A_3 ..... A_n
Machine B	B_1, B_2, B_3 ..... B_n

2. i) If the shortest processing time is A_r on machine A place the r^{th} job in the beginning of the sequence and do not consider it again.

   ii) If there is a tie among A_r q, look for the corresponding times in machine B. The job with largest time in B_q among ties is placed first in the sequence and the next job is placed after this in the sequence.

   iii) If here is a tie among B_q S, look for the corresponding times in machine A. The job with largest time in A_q among ties is placed last in the sequence and the next job is placed before this in the sequence.

3. The remaining (n – 1) jobs are sequenced by repeating steps 1 and 2 by deleting the processing times of the assigned jobs on both the machines.

4. The process is continued by placing the jobs next to first or next to last and so on till the optimum sequences obtained.

5. The total elapsed time and idle times for the optimum sequence are computed using the following formulae.

   a) Total Elapsed Time : Time between starting the first job in the optimum sequence on machine A and completing the last job in the optimum sequence on machine B.

   b) Idle Time on Machine A : (Time when the least job on the optimum sequence is completed on machine B).

   (Time when the last job on the optimum sequence is completed on machine A)

PROBLEMS

3. Five jobs are to be processed on two machine. Determine a sequence that will minimize the total completion time for this group of jobs. Processing times are as follows :

Jobs/Machines	J_1	J_2	J_3	J_4	J_5
M_1	10	5	15	22	3
M_2	6	8	12	4	15

Sol :

Jobs/Machines	J_1	J_2	J_3	J_4	J_5
M_1	10	5	15	22	3
M_2	6	8	12	4	15

Step 1 : Select the job with the shortest processing time. It is job J_5 on M_1 i.e., 3.

Step 2 : Since the shortest time is on machine 1, place the job J_5 in the first of the sequence eliminate job J_5 from further consideration.

Sequence	J_5				

Step 3 : Consider the remaining data

	J_1	J_2	J_3	J_4
M_1	10	5	15	22
M_2	6	8	12	4

Step 4 : Repeat step 1 – 3 for the remaining jobs. Shortest time is 3 of Job J_4 on M_2. Schedule it last and eliminate J_4.

Sequence	J_5				J_4

	J_1	J_2	J_3
M_1	10	5	15
M_2	6	8	12

The minimum among the remaining is

Time 5 for job J_2 on machine M_1.

Since the shortest time is one first machine, place this job J_2 in the beginning of the sequence after J_5.

Sequence	J_5	J_2			J_4

The job J_2 is eliminated from processing time table

	J_1	J_3
M_1	10	15
M_2	6	12

The shortest time is = 6 for Job (J_1) on machine 2.

Place this Job (J_1) last in the sequence before J_4.

Sequence	J_5	J_2		J_1	J_4

The only job remaining to be assigned is J_3 and place this in the gap in the sequence to get the optimum sequence.

Optimum Sequence	J_5	J_2	J_3	J_1	J_4

Step 5 : Computation of times

Jobs (As per optimum) Sequence	Machine M_1				Machine M_2			
	In time (Start)	Process Time	Out time (End)	Idle time	In time (Start)	Process Time	Out time (End)	Idle time Time
J_5	0	3	3	0	3	15	18	3
J_2	3	5	8	0	18	8	26	0
J_3	8	15	23	0	26	12	38	0
J_1	23	10	33	0	38	6	44	0
J_4	33	22	55	4	55	4	59	11
			Total	4			Total	14

Calculation to determine the throughout time and idle times.

For machine 1

Start time of job = End time of preceding job.

Idle time = Zero for all jobs except last job.

Last job idle time = end time of last job in machine 2 –end time of last job in machine 1

i.e., 59 – 55 = 4

For Machine 2

Start time = End time of preceding job on M_2

OR

= End time of corresponding job on M_1.

(Whichever is Max)

Total elapsed time = 14

To determine Idle Time of machine for each job.

Idle time = In time of that particular job – out time at predecessor job.

E.g. Idle time of J_2 = In time of J_2 – out time of J_1

On respective machine

Total idle time = 4 + 14 = 18

Optimal Sequence : $J_5 – J_2 – J_3 – J_1 – J_4$.

4. A group of six jobs is to be processed through a two machine flow shop. The first operation involves cleaning and the second involves painting. Determine a sequence that will minimize the total completion time for this group of jobs. Also compute the time.

Job	A	B	C	D	E	F
Cleaning (M_1)	5	4	8	2	6	12
Cleaning (M_2)	5	3	9	7	8	15

Sol :

Johnson's Rule

Step 1: Select the job with the shortest processing time. It is job D, with a time of 2 hours on M_1.

D						

Step 2: Do not consider job D, Job B is the next shortest time schedule it last and eliminate job B from further consideration.

D					B

Step 3: The remaining jobs are their times are

Job	A	C	D	E
M_1	5	8	6	12
M_2	5	9	8	15

Note that there si a tie for the shortest remaining time : Job A has the same time at each work i.e., cleaning and painting.

It makes no difference, then, whether we place it towards the beginning or the end of the sequence. Suppose it is placed towards the end. We now have

D				A	B

Step 4: Repeat step 1 – 3

D	E			A	B

The shortest remaining time is six hours for E.

Optimal sequences is

D	E	C	F	A	B

Step 5: Computation of time

Jobs	M_1 (Cleaning)				M_2 (Printing)			
	In Time	Process Time	Out Time	Idle Time	In Time	Process Time	Out Time	Idle Time
D	0	2	2	0	2	7	9	2
E	2	6	8	0	9	8	17	0
C	8	8	16	0	17	9	26	0
F	16	12	28	0	28	15	43	2
A	28	5	33	0	43	5	48	0
B	33	4	37	14	48	3	51	0
			Total	**14**			**Total**	**4**

Idle Time : For M_1

Start time of job = End time of preceding job

Idle time = Zero for all jobs except last job

Last job idle time on M_1 = End time of last job in M_2 – End time of last job in M_1

= 15 – 37 = 14 hrs.

For M_2

Start time = End time of preceding job on M_2

OR

= End time of corresponding job or M_1

(Whichever is maximum)

Idle Time

i) In the beginning 2 hours

ii) Difference between, job C on M_2 and job F on M_1

i.e., M_2 was idle for (28 – 26) 2 hrs.

Total idle time of M_2 is = 1 + i = 2 + 2 = 4 hrs

Total idle time = 14 + 4 = 18

2.4.3 Processing 'n' Jobs with three facilities/machines

Q22. State the procedure for Processing 'n' Jobs with three facilities/machines.

Ans :

If the problems are of N jobs on three machines, first it must be converted into TV jobs on two machines. Inorder to convert, the following procedure is followed,

Optimal solution for sequencing problems involving *'1C* jobs on three machines can be obtained by extending the Johnson's rule. To adopt this method, either or both of the following conditions should be satisfied. If not adopt CDs method.

Step 1

Consider three machines A, B and C on which '1C jobs have to be performed in the order ABC.

Condition 1

The minimum of the times for different jobs on machine A is at least equal to the maximum of the times of different jobs on machine B.

i.e., $\boxed{\min A_i \geq \max B_i}$

Condition 2

The minimum of the times for different jobs on machine C is at least equal to the maximum of the times of different jobs on machine B.

i.e., $\boxed{\min C_i \geq \max B_i}$

Step 2

Replace the given problem with the equivalent problem involving '1C jobs and two fictitious (imaginary) machines G and H with processing times as follows,

$G_i = A_i + B$. (i.e., i = 1, 2,..., n) and

$H_i = B_i + C$ (i.e., i = I, 2, ... , n)

Step 3

For problem obtained in step 2, apply the method of Johnson's rule adopted for sequencing '1C jobs through two machines.

Step 4

Identify the smallest processing times among G.'s and H's.

Step 5

If the smallest time is on machine G, place the job in the beginning of the sequence. If the smallest time is on machine H, place the job to the last in the sequence.

Step 6

Delete the assigned job from processing time, repeat steps 4 and 5 for the remaining jobs till all the jobs are assigned.

Step 7

The sequence so obtained is optimal sequence for the original problem and compute total elapsed time and idle time using this sequence for each machine.

PROBLEMS

5. In a both production five jobs A, B, C, D and E are required to be processed on three machines as detailed below. What is the optimum sequence and elapsed time ?

Process, Time on Machine	Jobs				
	A	B	C	D	E
Cleaning	7	6	8	9	10
Machinery	1	4	5	2	3
Painting	3	2	4	5	7

Sol :

Johnson's Rule

Step 1: Check of either of both the following conditions are satisfied.

Condition 1 :

Min Cleaning $\geq$ Max Matching

$6 \geq 5$ (Condition satisfied)

Condition 2 :

Min (Painting) $\geq$ Max (Machining)

$2 \geq 5$ (Condition satisfied)

Step 2: Creates a 2 fictitious machines H_i & G_i

H_i = Cleaning + Machining

G_i = Machining + Planning

Jobs	H_i	G_i
A	8	4
B	10	6
C	13	9
D	11	7
E	13	10

Step 3 : Apply Johnson's rule

Optimal Sequence | E | C | D | B | A |

Computation of Times

Job	Machine (Cleaning)				Machine (Matching)				Machine (Painting)			
	In Time	Process Time	Out Time	Idle Time	In Time	Process Time	Out Time	Idle Time	In Time	Process Time	Out Time	Idle Time
E	0	10	10	0	10	3	13	10	13	7	20	13
C	10	8	18	0	18	5	23	5	23	4	27	3
D	18	9	27	0	27	2	29	4	29	5	34	2
B	27	6	33	0	33	4	37	4	37	2	39	3
A	33	7	40	0 + 40	40	1	41	3 + 3	41	3	44	2
Total				4				29				23

Idle Time For

Cleaning = 4 min i.e., 0 + (44 – 40)

Matching = 29 min i.e., 26 + (44 – 41)

Painting = 23 min

Total elapsed time = 44 Minutes.

6. A factory received 6 jobs orders, which required processing on three machines M_1, M_2 and M_3. The factory operates for 40 hours a week. The time required by each job on the three machines is given below. On the basis of the given information determine whether the company needs to work overtime to finish all the tasks in a week's time.

Job	J_1	J_2	J_3	J_4	J_5	J_6
M_1	4	5	6	2	4	7
M_2	3	4	2	1	4	5
M_3	6	7	5	6	8	9

Sol :

Here 6 jobs have to be scheduled on three machines. In order to use Johnson's rule for solving the problem, any of the following conditions must be met.

Min $M_1 \geq$ Max M_2 (or) Min $M_3 \geq$ Max M_2

Now let us consider to virtual machines (Dummy) H_i and G_i for which the processing time can be calculated as

$H_i = M_1 + M_2$

$G_i = M_2 + M_3$

Jobs	$H_i = M_1 + M_2$	$G_i = M_2 + M_3$
J_1	7	9
J_2	9	11
J_3	8	7
J_4	3	7
J_5	8	12
J_6	12	14

Using Johnson's Rule, we get the optimal sequence as

J_4	J_1	J_4	J_2	J_6	J_3

Now based on this sequence we would calculate the total elapsed time.

Computation of Time

Job	M_1				M_2				M_3			
	In Time	Process Time	Out Time	Idle Time	In Time	Process Time	Out Time	Idle Time	In Time	Process Time	Out Time	Idle Time
J_4	0	2	0	0	2	1	3	2	3	6	9	3
J_1	2	4	6	0	6	3	9	3	9	6	15	0
J_5	6	4	10	0	10	4	14	1	15	8	23	0
J_2	10	5	15	0	15	4	19	1	23	7	30	0
J_6	15	7	22	0	22	5	27	3	30	9	39	0
J_3	22	6	28	16	28	2	30	1 + 14	39	5	44	0
Total				**16**				**25**				**3**

Total elapsed time

= Idle time of M_1 + Idle time of M_2 + Idle time of M_3

= 16 + 25 + 3 = 44 hrs.

7. Find the sequence that minimizes total machining time to complete the following data.

Job	A	B	C	D	E	F
M I	4	9	8	5	10	9
M II	5	4	3	6	2	5
M III	7	8	6	12	6	7

Sol :

Johnson's Rule (Extension)

Step 1 : Check the condition

Condition 1

Min M I $\geq$ Max M II

$4 \not\geq 6$

Condition not satisfied.

Condition 2

Min M III $\geq$ Max M II

6 = 6

Condition satisfied

Condition 2 has been satisfied. So proceed to step 2.

Step 2 : Create two dummy machine H_1, and G_1

H_i = I + II; G_i = II + III

Jobs	H_i	G_i
A	9	12
B	13	12
C	11	9
D	11	18
E	12	8
F	14	12

Step 3 : Apply Johnson's rule to the above table to get the optimal sequence.

Optimal Sequence

A	D	B	F	C	E

Computation of Time

Job	M_1				M_2				M_3			
	In Time	Process Time	Out Time	Idle Time	In Time	Process Time	Out Time	Idle Time	In Time	Process Time	Out Time	Idle Time
A	0	4	4	0	4	5	9	4	9	7	16	9
D	4	5	9	0	9	6	15	0	16	12	28	0
B	9	9	18	0	18	4	22	3	28	8	36	0
F	18	9	27	0	27	5	32	5	36	7	43	0
C	27	9	35	0	35	3	38	3	43	6	49	0
E	35	8	45	0 + 10	45	2	47	7 + 8	49	6	55	0
Total				**0 + 10**				**22 + 8**				**9**

Idle Time on

Machine I = 10

Machine II = 30

Machine III = 9

Total Idle time = 10 + 30 + 9 = 49 Hours.

8. Five jobs have to be processed on three machines X, Y,Z in the order X, Y and Z processing times are given below :

Jobs	Processing times (Minutes)		
	X	Y	Z
1	9	6	5
2	10	7	10
3	7	4	8
4	8	3	7
5	12	5	4

Determine the sequence that will minimize the elapsed time or cycle time. Find the idle time in each of the machines X, Y and Z.

Sol : **(Dec.-18)**

Johnson's Rule

Step - I :

Condition -1 : Min x $\geq$ max y

7 $\geq$ 7 (condition satisfied)

Condition - 2 : Min z $\geq$ max y

4 $\geq$ 7 (condition not satisfied)

Step - 2 :

Creates 2 ficitious machine H and G

H = x + y

G = y + z

Jobs	H	G
1	15	11
2	17	17
3	11	12
4	11	10
5	17	9

Step 3 : John's Rule

Optimal sequence | 3 | 2 | 1 | 4 | 5 |

Computation of time

Jobs	X				Y				Z			
	In Time	Process Time	Out Time	Idle Time	In Time	Process Time	Out Time	Idle Time	In Time	Process Time	Out Time	Idle Time
3	0	7	7	0	7	4	11	7	11	8	19	11
2	7	10	17	0	17	7	24	6	24	10	34	3
1	17	9	26	0	26	6	32	2	34	5	39	0
4	26	8	30	0	32	3	35	0	39	7	46	0
5	30	12	42	0+9	42	5	47	7+4	47	4	51	0
				9				26				14

Total idle time

x = 9

y = 26

z = 14

2.5 WORK STUDY

Q23. Define the term Work Study and State its objectives.

Ans : **(Dec.-20, Dec.-18)**

Meaning

Work study is defined as that body of knowledge concerned with the analysis of the work methods and the equipment used in performing a job, the design of an optimum work method and the standardization of proposed work methods. Work study has contributed immeasurably to the search for better methods, and the effective utilization of this management tool has helped in the accomplishment of higher productivity. Work study is a management tool to achieve higher productivity in any organization whether manufacturing tangible products (or) offering services to its customers.

Work study is also understood as a systematic, objective and critical examination of the factors, affecting productivity for the purpose of improvement. It make use of techniques of method study and work measurement to ensure the best possible use of human and material resources in carrying out a specific activity.

Objectives

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

Q24. What are the components of work study.

Ans :

Work Study is the systematic examination of the methods of carrying out activities such as to improve the effective use of resources and to set up standards of performance for the activities carried out.

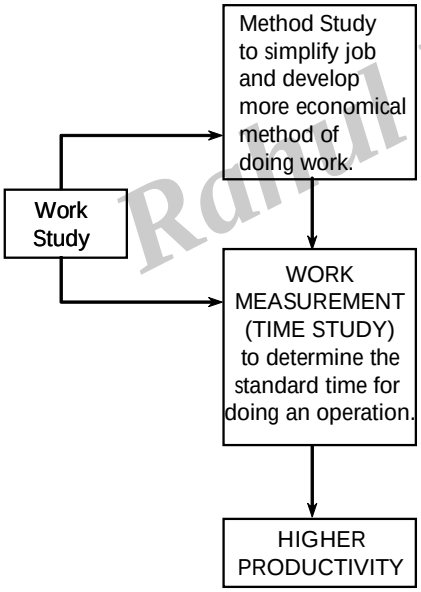
A generic term for those techniques, particularly method study and work measurement, which are used in the examination of human work in all its contexts, and which lead systematically to the investigation of all the factors which affect the efficiency and economy of the situation being reviewed, in order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

Components of Work Study

Work study is encompassed by two techniques i.e.

(i) Method Study

(ii) Work measurement.



(i) Method Study

Method study is systematic recording and critical examination existing and proposed ways of doing work, as a means of developing and applying easier and more effective methods and reducing costs.

(ii) Work Measurement

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

There is a close link between Method Study and Work Measurement. Method study is concerned with the reduction of the work content and establishing the one best way of doing the job where as work measurement is concerned with investigation and education of any ineffective time associated with the job and establishing time standards for an operation carries out as per standard method.

2.5.1 The concept and various techniques of methods analysis

Q25. Define method study. What are the objectives of method study?

Ans : **(Dec.-20, Dec.-18)**

Meaning

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. It is also known as methods improvement (or) work improvement. It encompasses the study of work processes, working conditions and equipments and tools used to carry out the job.

Method study may be understood as the systematic recording and critical examination of existing and proposed ways of doing work, as a means of developing and applying easier and more effective method and reducing costs.

Objectives

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.

Q26. Enumerate the steps involved in method study.

Ans :

The various steps involved in method study are :

1. Select

Select the work or job to be studied and define the objectives to be achieved by method study. The job selected to have maximum economic advantage, shall offer vast scope for work improvement through reduction of excessive material handling and fatigue to workmen, offer scope for improving the working conditions and improving the utilization of resources.

2. Record

Record all the relevant facts or informations pertaining to the existing method using the recording techniques such as -

(a) Process charts

(i) Outline process chart
(ii) Operation process chart
(iii) Flow process chart-material type, man type and machine type equipment type.
(iv) Man-machine chart
(v) Two handed process chart
(vi) Multiple activity chart
(vii) Simultaneous motion chart (SIMO chart)
(viii) Motion chart
(xi) Film analysis chart.

(b) Diagrams such as

(i) Flow diagram
(ii) String diagram
(iii) Cycle graph
(iv) Chronocycligraph

3. Examine

Examine the recorded facts critically challenging everything being done and seeking alternatives, questioning the purpose (What is achieved?), the means (How is it achieved ?), sequence.

4. Develop

Develop the improved method by generating several alternatives and selecting the best method. The factors to be considered while evaluating alternatives and selecting the best method are :

(a) Cost of implementation
(b) Expected savings in time and cost
(c) Feasibility
(d) Producibility
(e) Acceptance to design, production planning and control, quality control production and sales departments.
(f) Reaction of employees to the new method
(g) Short term or long term implication of the alternative.

Establish the new method by providing suitable equipment design, mechanical aids, jigs and fixtures, tools, working conditions, material handling equipments, workplace layout and work planning and control techniques.

5. Install

Install the improved (new) method in three phases planning, arranging and implementing phases. In the first two phases, the programme of installation and a schedule (i.e., time table) are planned and necessary requirements such as resources, equipments, tools, operating instructions to workers, are provided. The implementation phase involves the introduction of the developed method as standard practice to achieve the desired results.

6. Maintain

Maintain the new method by ensuring that the installed method is functioning well. This is done by periodic checks and verifications at regular intervals. Proper control procedures are used to ensure that the new method is practised to achieve the benefits of methods study and also to achieve higher productivity.

Q27. What are the various types of charts used in method study?

(OR)

Explain the various techniques of method analysis.

Ans : **(Dec.-20, Dec.-18)**

Process

1. **Outline process chart :** An outline process chart records an overall picture of the process and records only the main events sequence-wise. It considers only the main operations and inspections.

Standard Symbol	Name of Activity	Definition of Activity
●	Operation	Modification of an object at one work place. Object may be changed in any of its physical or chemical characteristics, assembled or disassembled or arranged for another operation, transportation, inspection or storage.
⇨	Transportation or movement	Change in location of an object from one place to another.
□	Inspection	Examination of an object to check on quality or quantity characteristics.
D	Delay/Temporary storage	Retention of an object in a location awaiting next activity.
▼	Storage	Retention of an object in location in storage which is protected against unauthorized removal.
□⇨	Combined	A combined activity occurs when two activity activities occur simultaneously. Various combinations of simultaneous occurrence of two activities could be possible.

Fig.: Symbols used in Process Charting

2. **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 of 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.

3. **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.

   Material or product type flow process chart records what happens to the material or product i.e., the changes the material or product undergoes in location or condition (includes operation and transportation). Man type process chart records the activities of a worker or operator i.e., what a worker or operator does, whereas equipment or machine .type flow process chart records the manner in which an equipment or machine is used.

4. **Two handed process chart:** In this chart the activities of a worker's or operator's both hands (or) limbs are recorded chronographically.

5. **Multiple activity chart :** In this chart the activities of more than one subject (worker, machine or equipment) are recorded on a common time scale to show their inter-relationship.

6. **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 srmultaneously.

7. **Flow diagram :** The flow diagram is a drawing or diagram drawn to a scale to show the relative position of a machine or equipment, jigs and fixtures, gangways or aisles and shows the path followed by materials or machines.

8. **String diagram :** It is a scale plan or model on which a string (or) a thread is used to trace and measure the path of workers, materials or equipments during a specified sequence of events.

9. **SIMO chart :** The simultaneous motion cycle chart (SIMO) is a type of two handed process chart in which the micromotions (therbligs) of both hands are recorded.

2.5.2 The concept and various techniques of work measurement

Q28. Define work measurement. What are the objectives of work measurement?

Ans :

Work measurement is defined as the application of techniques designed to establish the 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.

Objectives

Objectives of work measurement can be to achieve

1. Improved planning and control of activities or operations
2. More efficient manning of the plant
3. Reliable indices for labour performance
4. Reliable basis for labour cost control
5. Basis for sound incentive schemes

Q29. What are the benefits of work measurement?

Ans :

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 set standards of performances for labour utilization by establishing the labour standards for an element of work, operation or product under ordinary working condition.
4. To compare actual time taken by the worker with the allowed time (standard time) for proper control of labour.
5. To assist in labour cost estimation.
6. To provide information related to estimation of tenders, fixation of selling price and assessment of delivery schedule.

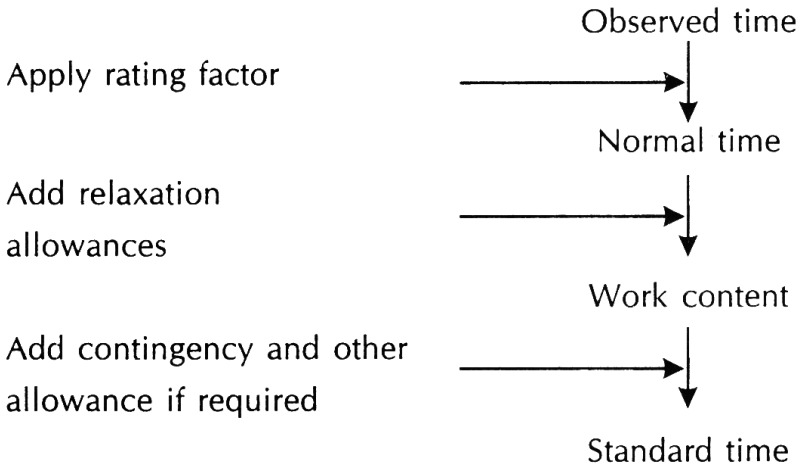
Q30. Enumerate the steps involved in work measurement.

Ans :

The various steps are :

1. Break the job into elements
2. Record the observed time for each element by means of either time study, synthesis (or) analytical estimating.
3. Establish elemental time values by extending observed time into normal time for each element by applying a rating factor.

4. Assess relaxation allowance for personal needs and physical and mental fatigue involved in carrying out each element.
5. Add the relaxation allowance time to the normal time for each element to arrive at the work content.
6. Determine the frequency of occurrences of each element in the job, multiply the work content of each element by its frequency (i.e., number of time the element occurs in the job) and add up the times to arrive at the work content for the job.
7. Add contingency allowance if any to arrive at the standard time to do the job.



Q31. Explain the techniques of work measurement.

Ans :

(i) 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 is defined by ILO as below "Time study is a work measurement technique for recording the times and rates of working for the elements of a specified job carried out under specified conditions and for analysing the data so as to obtain the time necessary for carrying out the job at a defined level of performance

Objectives

(a) To furnish a basis of comparison for determining operating effectiveness.

(b) To set labour standard for satisfactory performance.

(c) To compare alternative methods in method study in order to select the best method.

(d) To determine standard costs.

(e) To determine equipment and labour requirements.

(f) To determine basic times/normal times.

(g) To determine the number of machines an operator can handle.

(h) To balance the work of operators in production or assembly lines.

(i) To provide a basis for setting piece rate or incentive wages.

(j) To set the completion schedules for individual operations or jobs.

(k) To determine the cycle time for completion of a job.

(ii) 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.'

Advantage

1. Reliable as the built-up time values of the 'standard data' catalogue are based on data derived from a large number of time studies.
2. Economical as less time is required when compared to 'stop watch' time study.
3. Used for estimating labour times for preparing cost estimates for new jobs for which the selling price has to be quoted to customers.

(iii) Analytical Estimating

This technique of work measurement is used to determine the time values for jobs having long and non-repetitive operations. The time values are determined by using synthetic data (or) on the basis of the past experience of the work study engineer, when no synthetic (or) standard data is available. It is essential that the estimator must have adequate experience of estimating, motion study, time study and the use of standard data (or synthesised time standards).

Advantages

(a) Offers the same advantages enjoyed by synthesis method.

(b) Helps in planning and scheduling the production.

(c) Provides a basis for fixing the labour rate for non-repetitive jobs.

(d) Steps to improve labour control.

(iv) 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.

PMTS is an improvement over motion study because besides affording detailed analysis of the motion, it makes it possible to set a measure of the time that a series of motion ought to take.

Predetermined time standards are standard data for wide variety of basic body motions which are common in many industrial operations.

For example, some of the basic or elementary human body motions are 'move' 'reach', 'position' etc., Predetermined time standards contain table of standard time values for such basic motions.

Advantages

1. Affords fine analysis and improvement of work methods.
2. Since the time for each basic motion is predetermined, the computation of standard time for a job or an operation is faster and more economical than time study using stop watch.
3. Offers a precise means of recording time, avoiding subjective judgement or bias of the rater.
4. Involves no interference in the normal work routine and hence faces little resistance from workers.
5. More effective and economical tool for work measurement for repetitive jobs of short duration.

Disadvantages

1. Such standards are not available for each and every human activity.
2. Limited to only uninhibited work in its application i.e., for the work which does net involve motions restricted by the process.
3. Has limited application in non-repetitive and office activities.
4. Fairly long period of intensive training under expert guidance is necessary to use this technique.

(v) 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.

These studies are frequently used to estimate the percentage of time spent by the employees in unavoidable delays (commonly called ratio-delay studies), repairing finished products from an operation, and supplying material to an operation.

Steps in Work Sampling

The work sampling study consists of essentially the following steps :

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.

PROBLEM

9. An industrial operation consists of the following observed times along with their performance rating.

Element	A	B	C	D	E	F
Observed Time (minutes)	0.20	0.10	0.50	0.12	0.18	0.25
Performance rating %	80	85	90	75	85	90

Assuming rest and personal allowance as 15% and contingency allowance as 4% of the basic time. Calculate standard time per piece.

Sol : **(July-18)**

Element	Observed time (min)	Performance rating%	Normal time
A	0.20	80% = 0.80	0.160
B	0.10	0.85	0.085
C	0.50	0.90	0.450
D	0.12	0.75	0.090
E	0.18	0.85	0.153
F	0.25	0.90	0.225
		Total	**1.163**

1. Normal time = Observed time × Performance rating
2. Normal time (or) Basic time = 1.163 minutes
3. Rest and personal allowances = 15% × 1.163

   = 0.174

   Contingency allowances = 4% × 1.163

   = 0.047

   Standard time per piece = (1) + (2) + (3)

   = 1.163 + 0.174 + 0.047

   = 1.384

   Standard time per piece = 1.384 minutes.

10. 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 ?

Sol :

$$\begin{pmatrix}\text{Observed}\\ \text{Time}\end{pmatrix} \times \begin{pmatrix}\text{Observed}\\ \text{Rating}\end{pmatrix} = \begin{pmatrix}\text{Basic or}\\ \text{Normal time}\end{pmatrix} \times \begin{pmatrix}\text{Standard}\\ \text{Rating}\end{pmatrix}$$

$$\therefore \quad \text{Observed time} = \frac{(\text{Basic or Normal time}) \times (\text{Standard rating})}{\text{Observed rating}}$$

Date : Basic or Normal time = 20 seconds

given Standard rating = 100

For observation No.1, Observed rating = 100

$$\therefore \quad \text{Observed time} = \frac{20 \times 100}{100} = 20 \text{ seconds}$$

For observation No.2, $\text{Observed time} = \frac{20 \times 100}{125} = 16$ seconds

For observation No.3, $\text{Observed time} = \frac{20 \times 100}{80} = 25$ seconds

11. 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.

Sol :

Observed time for 320 units = Working time - Idle time

$= 8 - 8 \times 0.15 = 8 - 1.2 = 6.8$ hours

$= 6.8 \times 60 = 408$ minutes.

$$\text{Observed time per unit} = \frac{408}{320} = 1.275 \text{ minutes}$$

$$\text{Normal time per unit} = \frac{\text{Observed time/Unit} \times \text{Observed rating}}{\text{Standard rating}}$$

$= \text{Observed time/unit} \times \text{Performance rating}$

$$= \frac{1.275 \times 120}{100} = 1.53 \text{ minutes}$$

Standard time/unit = Normal time/unit + Allowances

= 1.53 minutes + 12% of 1.53 minutes

$= 1.53 + \frac{12}{100} \times 1.53$

= (1.53 + 0.184) minutes

= 1.714 minutes

12. 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 = 331/3% of normal time.

Sol :

Normal time per unit = Observed time/unit × Rating facto

$= 5 \times \frac{120}{100} = 6$ minutes

Allowances = 331/3% of normal time

$= \frac{33.33 \times 6}{100} = 2$ minutes

Standard time/unit = Normal time/unit + Allowances

= 6 + 2 = 8 minutes/unit

Standard production in shift of 8 hours $= \frac{8 \times 60}{8} = 60$ units.

Exercise Problems

1. Find the sequence that minimizes the total elapsed time required to complete the following tasks. Each job is processed in the order I - II - III.

Job	A	B	C	D	E	F	G
Machine I	12	6	5	11	5	7	6
Machine II	7	8	9	4	7	8	3
Machine III	3	4	1	5	2	3	4

[Ans: Elapsed time : 59 hours]

2. There are five jobs, each of which must go through machines A, B and C in the order ABC. Processing times (in hours) are given in the following table.

Job	1	2	3	4	5
Machine A	8	10	6	7	11
Machine B	5	6	2	3	4
Machine C	4	9	8	6	5

[Ans: Minimum time is : 51 hours]

3. Determine the optimal sequence and idle time of each machine that will minimize the total elapsed time.

Job No.	1	2	3	4	5
Machine A	5	7	6	9	5
Machine B	2	1	4	5	3
Machine C	3	7	5	6	7

[Ans: Elapsed time = 4-hours; Idle time is 8 hrs on machine A, 25 hrs on Machine B and 12 hrs on Machine C]

4. A machine shop has six machines A, B, C, D, E and F. Two jobs must be processed through each of machines. The times one machines and the necessary sequence of the jobs through the shop are given below.

Order	1	2	3	4	5	6
Job - I	A - 20	C - 10	D - 10	B - 30	E - 25	F – 16
Job - II	A - 10	C - 30	B - 15	D - 10	F - 15	E - 20

[Ans: Minimum total time = 150 hrs]

Short Question & Answers

1. Plant layout

Ans :

A plant layout refers to the arrangement of machinery, equipment and other industria facilities such as receiving and shipping departments, tool rooms, maintenance rooms and employee amenities for the purpose of achieving the quickest and smoothest production a- the least cost. The subject of plant layout not only covers the initial layout of machines and other facilities but encompasses improvement in, (or) revisions of, the existing layout in the light of subsequent developments in the methods of production. In other words, a plat layout is a floor plan for determining and arranging the desired machinery and equipment of a plant, whether established or contemplated, in the one best place to permit the quickes flow of material at the lowest cost and with the least amount of handling in processing the product from the receipt of the raw materials to the shipment of the finished products.

Definitions

(i) According to Knowles "Planning and arranging manufacturing machinery, equipment, and services for the firs' time in completely new plants;

(ii) According to Thomson The improvements in layouts already in use in order to introduce new methods an improvements in manufacturing procedures.'

2. Work Study

Ans :

Work study is defined as that body of knowledge concerned with the analysis of the work methods and the equipment used in performing a job, the design of an optimum work method and the standardization of proposed work methods. Work study has contributed immeasurably to the search for better methods, and the effective utilization of this management tool has helped in the accomplishment of higher productivity. Work study is a management tool to achieve higher productivity in any organization whether manufacturing tangible products (or) offering services to its customers.

Work study is also understood as a systematic, objective and critical examination of the factors, affecting productivity for the purpose of improvement. It make use of techniques of method study and work measurement to ensure the best possible use of human and material resources in carrying out a specific activity.

3. Plant Location

Ans :

A plant is a place, where men, materials, money, machinery and equipment, etc., are brought together for manufacturing product. Plant location decisions are crucial because they commit organizations to long lasting financial, employment, a distribution patterns. As such, they deserve the careful attention of finance, personnel, marketing and other managers, as well as that of the operations mangers who manage the facilities.

Plant location is not a static decision that can be made and forgotten. Plant layout or facility layout choices follow the location decisions. They influence the type of equipment and level of technology employed, the flow of work and design of jobs, inventory levels, and other operating characteristics of the firm. Layout can be changed more easily than locations. However, they represent more of a continuing concern. In addition, they fall more directly within the responsibility of operations manager because they deal with the physical arrangement of productive facilities.

4. Elapsed Time

Ans :

Time between starting the first job in the optimum sequence on machine A and completing the last job in the optimum sequence on machine B.

5. Define Capacity.

Ans :

Capacity is amount of output a system is capable of achieving over a specific period of time. Capacity of a plant is the ability of the plant to meet the demand in terms of products or services offered by the plant. Capacity represents the maximum rate of output of a facility. Capacity affects the company's ability to meet market demand, the types of markets it can enter and its ability to compete in those markets.

6. Importance of capacity planning.

Ans :

(i) Capacity decisions have an impact on the ability of the organization to meet future demands for products and Services.

(ii) Capacity decisions affect operating costs. It should be seen that capacity and demand requirements will be matched, which will tend to minimize operating costs. In practice, this is not always achieved because actual demand either differs from expected demand or tends to vary. In such cases, a decision might be made to attempt to balance the costs of over and under capacity.

(iii) Capacity is usually a major determinant of initial cost.

(iv) Capacity decisions often involve long-term commitment of funds.

(v) Capacity decisions can affect competitiveness.

(vi) Capacity planning reduces the complexity in manufacturing operation.

7. Fixed position Layout.

Ans :

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. It also called the fixed location layout, this type is followed in the manufacture of bulky and heavy products, such as locomotives, ships, boilers, air craft and generators. The construction of a building requires a fixed location layout because men, cement, sand, bricks, steel, wood and others, are taken to the site of the construction. This is equally true of a brick kiln. Another example is that of a hospital, where doctors and nurses (workers) and medicines and other paraphernalia (materials) are taken to the patient (product).

8. Combined Layout.

Ans :

The application of the principles of product layout, process layout (or) fixed location layout in their strict meanings is difficult to come across. A combination of the product and process layouts, with an emphasis on either, is noticed in most industrial establishments. Plants are never laid out in either pure form. It is possible to have both types of layout in an efficiently combined form if the products manufactured are somewhat similar and not complex.

In plants involving the fabrication of parts and assembly, fabrication tends to employ the process layout, while the assembly areas often employ the product layout. In soap manufacturing plants, the machinery manufacturing soap is arranged on the product-line principle but ancillary services, such as heating, the manufacturing of glycerine, the power house, the water treatment plant are arranged on a functional basis.

The departments in are arranged cording to the types of processes but the products flow through on a product layout.

9. Components of Work Study

Ans :

(i) Method Study

Method study is systematic recording and critical examination existing and proposed ways of doing work, as a means of developing and applying easier and more effective methods and reducing costs.

(ii) Work Measurement

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

There is a close link between Method Study and Work Measurement. Method study is concerned with the reduction of the work content and establishing the one best way of doing the job where as work measurement is concerned with investigation and education of any ineffective time associated with the job and establishing time standards for an operation carries out as per standard method.

10. Objectives of method study

Ans :

(i) To study the existing proposed method of doing any job, operation or activity.

(ii) To develop an improved method to improve productivity and to reduce operating costs

(iii) To reduce excessive material handling (or) movement and thereby reduce fatigue to workmen.

(iv) To improve utilization of resources.

(v) To eliminate wasteful and inefficient motions.

(vi) To standardise work methods (or) processes, working conditions, machinery, equipments and tools.

11. Time Study

Ans :

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 is defined by ILO as below "Time study is a work measurement technique for recording the times and rates of working for the elements of a specified job carried out under specified conditions and for analysing the data so as to obtain the time necessary for carrying out the job at a defined level of performance

Objectives

(a) To furnish a basis of comparison for determining operating effectiveness.

(b) To set labour standard for satisfactory performance.

(c) To compare alternative methods in method study in order to select the best method.

(d) To determine standard costs.

12. Predetermined Motion Time System (PMTS)

Ans :

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.

PMTS is an improvement over motion study because besides affording detailed analysis of the motion, it makes it possible to set a measure of the time that a series of motion ought to take.

Predetermined time standards are standard data for wide variety of basic body motions which are common in many industrial operations.

For example, some of the basic or elementary human body motions are 'move' 'reach', 'position' etc., Predetermined time standards contain table of standard time values for such basic motions.

13. Work Sampling

Ans :

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.

These studies are frequently used to estimate the percentage of time spent by the employees in unavoidable delays (commonly called ratio-delay studies), repairing finished products from an operation, and supplying material to an operation.

Choose the Correct Answers

1. The time allotted for completing a task at standard performance is [a]

   (a) Standard time (b) Allowed time

   (c) Basic time (d) Standard rate

2. In which type of service operation, there will be high level of customer involvement? [b]

   (a) Customer-as-product service operation

   (b) Customer-as-participant service operation

   (c) Quasi-manufacturing service operation

   (d) None of the above

3. Which of the following comes under the dimensions of service quality? [c]

   (a) Reliability (b) Responsiveness

   (c) Both (a) and (b) (d) All the above

4. Services are characterized as, [d]

   (a) Intangible (b) Inconsistent

   (c) Inseparable (d) All the above

5. A service environment made up of factors like values, norms, beliefs, rituals etc., is known as [a]

   (a) Service culture (b) Service innovation

   (c) Service quality (d) Service positioning

6. PMTS stands for [c]

   (a) Predictable Motion Time System (b) Perfect Motion Time System

   (c) Predetermined Motion Time System (d) Percentage Motion Time System

7. In the process charts, which is the symbol used for 'Inspection'? [c]

   (a)  (b) 

   (c)  (d) 

8. _____ refers to a systematic arrangement of machines in one line on the basis of sequence of operations. [c]

   (a) Fixed position layout (b) Process layout

   (c) Product layout (d) Cellular layout

9. _____ is the process of maintaining the activities which are handled before the machines or equipments fails. [d]

(a) Breakdown maintenance (b) Routine maintenance

(c) Predictive maintenance (d) Preventive maintenance

10. _____ mainly deals with the repairs which are made after the equipment or machine is out of order. [b]

(a) Total productive maintenance (b) Breakdown maintenance

(c) Preventive Maintenance (d) Planned maintenance]

11. Which of the following is wrong in assumptions of sequencing 2 machines × n jobs by Johnson's Rule [d]

(a) No passing is allowed

(b) Processing times are known

(c) Time of moving job from one machine to the other is negligible

(d) The time of processing is dependent on order of processing

12. According to Johnson's rule, the smallest processing time if occurs in [a]

(a) First series, place it in the first available position

(b) Second series, place it in first available position

(c) First series, place it middle

(d) Second series, place it middle

13. Which of the following does not characteise the sequencing problem. [d]

(a) No passing rule

(b) idle time of machine

(c) Number of machines and number of jobs

(d) Number of movements while processing the jobs

14. The fundamental assumption for Johnson's method of sequencing is _____. [a]

(a) No passing rule

(b) Passing, rule

(c) Similar machines must be used for first and second process

(d) Non zero process time

15. If a job has zero process time for any machine the job must. [c]

(a) Posses first position only (b) Possess last position only

(c) Possess extreme position (d) Be deleted from the sequencing

Fill in the Blanks

1. _____ is a function of deciding the place where the plant must be located for maximizing the operating economy and its effectiveness.

2. _____ deals with the estimation of both the long and short term capacity requirements of a concern.

3. A _____ decides the quantity of each finished product which needs to be completed in each time period.

4. Breakdown maintenance is also called as _____.

5. _____ refers to the physical arrangement of plant and different parts of plant.

6. _____ is the process of determining the processing sequence of all the jobs at each work centre or machine.

7. _____ is a production management function which deals with the routine problem of maintaining the physical plant in good working condition.

8. The two main components of work study are method study and _____.

9. Activity sampling is also known as _____.

10. _____ is defined as "the usage of techniques which are developed by the experienced and professional workers plan and create the work content of a particular task by ascertaining the time needed to perform the work as per the predetermined standards".

11. If there is some least process time for two jobs in both series, then the sequencing problem will have _____.

12. According to Johnson's rule if smallest processing time appears in 2nd M/C series, then its position in the sequence is _____.

13. If process time for job is zero in 1st series, then this job should occupy _____ position.

14. The idle time of second machine decreases if the job with _____ process time is taken first on first machine.

15. If passing is allowed, the sequencing problem becomes a case in _____ problem.

ANSWERS

1. Plant location
2. Capacity planning
3. Master Production Schedule
4. Corrective maintenance.
5. Layout
6. Sequencing
7. Maintenance
8. Work measurement
9. Work sampling
10. Work measurement
11. Alternate or multiple optimal solution
12. Least available or extreme right
13. First position
14. Lowest or minimum
15. Assignment

UNIT III

PURCHASE AND STORES MANAGEMENT :

Purchase Management: Sources of Supply of Materials, selection, evaluation of Vendors. Methods of vendor rating.

Stores Management: Functions of Stores and Materials control. Classification, Codification, Simplification and Standardization of materials. Economic Order Quantity. Selective Inventory Control Techniques: ABC, VED, FNSD & XYZ.

3.1 Purchase Management

Q1. What is Purchase Management? What are the objectives of Purchase Management?

Ans :

Purchasing management refers to the effective management of raw materials/inputs purchased for manufacture infinished goods. Purchasing management basically aims at purchasing appropriate raw materials and other items and reducing costs to the maximum extent. Specific features of purchasing management includes,

- Ensuring continuous supply of raw materials/ inputs.
- Purchasing appropriate inputs at right time, right price and in right quantity and quality.
- Analyzing suppliers market and selecting best suitable vendor.

Objectives

1. To pay reasonably low prices for the best values obtainable, negotiating and executing all company commitments.
2. To keep inventories as low as is consistent with maintaining production.
3. To develop satisfactory sources of supply and maintain good relations with them.
4. To secure good vendor performance including prompt deliveries and acceptable quality.
5. To locate new materials or products as required.
6. To develop good procedures, together with adequate controls and purchasing policy.
7. To implement such programmes as value analysis, cost analysis, and make-or-buy to reduce cost of purchases.
8. To secure high calibre personnel and allow each to develop to his/her maximum ability.
9. To maintain as economical a department as is possible, commensurate with good performance.
10. To keep top management informed of material development which could affect company profit or performance.
11. To achieve a high degree of co-operation and co-ordination with other departments in the organization.

3.1.1 Sources of Supply of Materials

Q2. What are the different source of supply that a firm should consider to develop potential suppliers?

Ans :

1. Trade Directories

There are several trade directories available, both national and foreign. Some deal with manufacturers and suppliers of all kind of material while some are specialized like exclusive chemical or engineering goods manufacturing.

Information on addresses, regional offices, types and range of products and addresses of agents and dealers will be posted in these directories. On line trade directories are also fast growing. There are international agencies who have word wide suppliers listed in their

computer storage systems which, one can have access to from any part of the world. In India also such computer based trade directories are being developed quite rapidly.

2. Trade Journals

Many leading companies advertise in trade journals and this forms important source of information about suppliers. A purchasing department benefits considerably if it contributes to journals, which contain information relevant to their businesses. Such relevant information can be classified, indexed updated and maintained in proper files.

3. Telephone Directories

Most telephone directories contain considerable number of advertisements alphabetically arranged item wise or group wise like air conditions, castings, paperboard, etc. This is a valuable source of information on suppliers. Most of the advertisers in telephone directory are local companies.

4. Supplier's Catalogues

Many manufacturers produce catalogues or pamphlets giving details of the products they manufacturers. These catalogues can be easily obtained on request. These catalogues contain technical information, specifications, performance characteristics, price, etc. Filing of such catalogues will be useful for future references.

5. Trade Exhibitions and Fairs

Exhibitions and fairs are useful for obtaining information on new suppliers, new products or modifications of old products. Visiting exhibitions of specialist products like textile machinery, motors, office equipment, electronic equipment, etc., provides an excellent means of expanding a buyer's knowledge of new products and new suppliers.

6. Salesmen

Sometimes firms send their sales people for giving information related to their businesses to the perspective purchasers. Because of their specialized knowledge, salesmen can suggest new applications for their products, which in some cases may eliminate the search for new vendors. An alert buyer can tap their information by a right approach. Salesmen should be treated with utmost courtesy and given enough opportunity to make their sales presentations.

7. Company Personnel

Employees of other departments like engineering, sales, design, R&D, etc., within the company are another source of information on suppliers. Through their personal and professional associations these people learn about new suppliers. The purchasing department can best tap this source by maintaining cordial relationship with other departments.

8. Other Companies

Mutual exchange of information with purchase departments of other companies can be extremely beneficial not only for information about suppliers but also for evaluation and price comparison.

9. Public Tenders

This is one of the most common source of securing supplier information. The buyer states the product he wants and gives specifications or terms of purchase. Potential suppliers send their quotations.

3.1.2 Selection of Vendor

Q3. What are the factors and issues in selection of suppliers?

Ans :

Factors in selection of Suppliers

While selecting a source a firm must consider several factors.

Some of the factors which must be considered for selecting a source are as follows:

1. Lead Time And On-Time Delivery

A firm must determine the lead times, that the supplier provides. They need to verify the procedures, which a supplier follows for

ensuring timely deliveries and for documenting and correcting delivery problems.

2. Quality Assurance

The Quality provided by a supplier, must be examined by a finn. The procedures followed by the supplier for controlling and assuming the quality must be evaluated by the firm. It must analyze, whether the supplied takes corrective actions for quality document and conducts 'investigations for ascertaining and correcting the cause of non conforming materials.

3. Flexibility

The firm must evaluate the Flexibility of a supplier in handling the changes in, quantity, delivery schedules and product or service changes.

4. Location

A firm mostly prefers a supplier who is located near its own location as it consumes less time. So, a firm determines whether a supplier is located near to the firm or not.

5. Price

A firm must determine, whether the supplier is setting reasonable prices if he is providing the entire package and does he want to negotiate the prices.

6. Product or Service Changes

A firm considers the suppliers, who are financially stable and provides a notification, when they make any alternations in products or services.

7. Other Factors

The firms must ascertain, whether the supply depends on other buyers or not, as it leads to a risk of giving more preference to the needs of other buyers over the needs of the firm.

Issues in Selection of Suppliers

The following are the issues to be resolved while selecting the suppliers.

1. One or More Suppliers

Purchasing entire lot from one supplier earns quantity discounts for the firm; but makes it dependent on solely one supplier. There is the risk of putting all the eggs in one basket. The advantage of having multiple suppliers is that failure on part of one supplier can be adjusted by purchasing more from other suppliers. One source means consistency in quality. Two sources mean competition in improving quality. The buying organization must evaluate all these considering the criticality of the product and its availability.

2. Agent or Manufacturer

If purchasing directly from the manufacturer is cheaper, it might be really not so when one considers the overall gains through service facilities. Stockists are available locally and have direct interest in their customers and related services.

The amount of resources spent in purchasing from the stockiest in terms of paper work, follow-up, etc., is much less than in purchasing directly from the manufacturer. Again, the decision will depend upon the nature of the product in question.

3. Local (or) Distant Supplier

Where everything is almost equal, local supplier is always the best. Distant suppliers increase costs on transport, packaging, insurance, sales tax, octroi, etc., and there is also the difficulty of follow-up. Local source suits best to meet urgent purchase requirements and where local relationships matter for resolving disputes.

Efficiencies of distant and local suppliers should be thoroughly analyses before making final choice.

4. Reciprocity

Many organizations have a mutual arrangement with their suppliers whereby they purchase goods for the same consideration. This is called reciprocity. But such arrange-

ments should be made considering absolute advantages and without adversely affecting any purchase requirements.

Q4. What are the steps involved in selection of a vendor.

Ans :

Step-1: Searching

In this step, various sources of supply of materials are searched.

Step-2: Selection

Selection of right source/supplier is one of the primary objectives of the firm. The purchase department is responsible for selecting the right supplier for the firm.

The basic factor which must be considered by the firm while selecting a source are lead time and on-time delivery, quality assurance, flexibility, location, price, product/service changes etc. Apart from these factors, the various other factors include,

(a) Production Abilities of Vendor

The production abilities of a vendor are,

(i) The vendor should be able to manufacture the desired product in desired quantities.

(ii) The vendor must have the ability to expand the capacity in future.

(iii) The vendor must have the knowledge about buying company and its requirements.

(b) Financial Soundness of the Company

The financial soundness of the company depends on the following factors,

(i) The capital structure of vendor's company.

(ii) The past profitability records of the company and

(iii) Future expansion plans of the company.

(c) Technical Capabilities

The technical capabilities of a vendor are,

(i) Vendor should have adequate technical capabilities.

(ii) Vendor must have consistency in the quantity produced by the firm.

(iii) Vendor must follow proper quality control methods.

(d) Other Considerations

The other factors that should be considered are,

(i) Working conditions of vendor company.

(ii) Industrial relations in the vendor companies.

(iii) Any possibility of disruptions in supply of materials in qualitative and quantitative terms due to human relations problems in the vendor company.

Step-3: Negotiation and Trial Orders

The firms give trial orders to the suppliers for analyzing their technical capabilities of suppliers. Negotiation is a part of a buyer's day to day Operations. A Purchasing Executive must determine whether the negotiation is done for cost, quality or for quantity. One must have the complete cost data and technical data of their own company as well as their supplier companies. A Purchasing Executive needs to have information about the changing economic, technological and other trends in its own region or in the country. This information helps the buyer in supporting his statements or demands and makes them understand the difficulties and problems faced by the suppliers. Several effective buyers who conduct purchasing research have the ability to recommend methods for decreasing costs and improving quality, delivery or performance to their supplier company.

Step-4:Rating

Vendor Rating is a continuous management process used for the assessment of vendors. It is engaged in measuring, evaluating and improving the supplier performance, which helps the firms in making future sourcing decisions.

3.1.3 Evaluation of Vendors

Q5. How do you evaluate the performance of suppliers?

Ans :

Generally, the firms compare the suppliers, by considering only the quoted price and neglect the fact that, suppliers also differ on certain important aspects, which influence the total cost of using a supplier.

1. Replenishment Lead Time

Evaluating the supplier's performance with regard to replenishment lead time helps the firm to determine how each supplier affects the cost of holding a safety inventory. When the replenishment lead time from a supplier increases, the buyer needs to increase his safety inventory levels, as it grows proportional to the square root of replenishment lead time.

2. On-time Performance

The on-time performance, influences the variability of the lead time. A reliable supplier has a low variability and an unreliable vendor has a high variability. With an increase in the lead time variability, the needed safety inventory at the firm increases proportionally.

3. Supply Flexibility

It is the extent of variation in order quantity which a supplier allows without allowing other performance factors to depreciate. If the supplier is less flexible, then the lead time variability will be more and is shown as order quantities change. Hence, the level of safety inventory which a firm has to carry, is influenced by supply flexibility.

4. Delivery Frequency/Minimum Lot Size

The size of each replenishment lot ordered by a firm is influenced, by the delivery frequency and the minimum lot size provided by the supplier. With an increase in the replenishment lot size, the cycle inventory at the firm also increases, resulting in an increase in the cost of holding inventory.

The required safety inventory is influenced by delivery frequency in a firm using a periodic review policy.

5. Supply Quality

The lead time and lead time variability of the suppliers are influenced by the supply quality, as the follow up orders must be fulfilled, for replacing the defective products. Due to this, the firm has to hold more safety inventory from a low quality supplier, when compared to high quality supplier. After the relationship between the supply quality, lead time and lead time variability is determined, the suppliers quality level can be transformed into the required safety inventory and related holding cost. The quality also influences the customer satisfaction, due to rework, lost material and inspection cost.

6. Inbound Transportation Cost

The suppliers cost not only depends on the distance, type of transportation, delivery frequency but also on the inbound transportation cost.

3.2 VENDOR RATING

Q6. What is Vendor Rating? Explain the factors determining Vendor Rating.

Ans : **(Imp.)**

Meanings

Vendor rating is a continuous management process used for the assessment of vendors. It is engaged in measuring, evaluating and improving the supplier performance which helps the firm in making future sourcing decisions.

Factors

The following are the factors determining the vendor rating.

1. Price

Price is one of the most important consideration while making any type of purchases. Price is the major factor, which is observed keenly by any firm before making purchases.

2. Quick Delivery

Normally, companies prefer only those vendors (suppliers) who provide quick

delivery or, on time delivery of products. Supplying firms can provide this facility to the companies by maintaining the stock in the form of warehousing.

3. Inventory Plans

Suppliers should make plans for storing the stock as this enables them to accept the proposals and deliver the products at right time. Effective planning of inventory and its storage by suppliers usually increases demand for their products and enables efficient delivery system.

4. Market Information

Suppliers should keep the track of current market information with respect to customer expectations, taste and preferences, customers buying behavior etc., as this helps them to produce the products preferred by the customers. A purchasing company also keeps record of present market situation and prefers only those suppliers/vendors who produce the products as per the demand. Market information is one of the major factor determining the vendor.

5. Service

Different services are offered by different suppliers. Suppliers usually provide services like, machinery repairs when breakdown or failure occurs, replacement of item when it is found defective/damaged, gives instructions for how to operate machinery or equipment etc. The Purchasing Company while rating the vendors, considers the above aspects and rates them as per their needs/requirements.

6. Co-Operation

Cooperation acts as key aspect to enhance the productivity as well as profitability. Suppliers should cooperate with the purchasing firms during sales as it helps in building strong relationship between them.

7. Financial Position

Suppliers should maintain their financial status, as it indicates suppliers capabilities with regard to producing a product, offering quality product, prompt delivery, etc. The purchasing company prefers only those suppliers who offer products with good quality and quick delivery.

8. Freight and Delivery Charges

Suppliers should give certain discounts to the purchasing companies, at the time of sales. For instance, less freight charges, no installation cost on machinery/equipment, less charges for delivery, etc. Purchasing firms consider these costs at the time of vendor rating.

9. Credit Facilities

Suppliers should provide credit facilities to the purchasing companies such as, allowing partial payment at the time of purchases and the rest of the payment at the time of delivery or within the specified time limit. Purchasing companies consider credits facilities provided by suppliers, while rating the vendors.

3.2.1 Methods of Vendor Rating

Q7. Describe the various methods of Vendor Rating.

Ans : **(Imp.)**

(i) Categorical Plan

Under this plan, personnel from various divisions maintain informal evaluation records. Individuals involved traditionally include personnel from purchasing, engineering, quality control, inspection and receiving. For each major supplier, each, person prepares a list performance factors which are important to him. At a monthly meeting, each major supplier is evaluated against each evaluator's list of factors. Each supplier is then assigned an over group evaluation, usually expressed in simple categorical terms such as 'preferred', 'neutra or 'unsatisfactory'.

(ii) The Weighted Point Plan

Under this plan, the performance factors to be evaluated (quality delivery, price and services) are given "weights", for instance, quality might be weighted 25, delivery 20, price 30 and service 25. The weights selected in any specific situation represent buyer's

judgement about the relative importance of the respective factors.

After the performance factors have been selected a specific procedure must be developed for measuring actual vendor performance on each individual factor. Supplier performance on each factor must be expressed in quantitative terms. To determine a supplier's overall rating, each factor weight is multiplied by the supplier's corresponding performance number; these products (for each factor) are then totalled to get the supplier's final rating for the period in question.

The responsibility of vendors rating shall rest with a committee comprising Chief/ Sr. Commercial Manager, Quality Control Manager, Accounts Manager, and Chief Production Engineer. This Committee shall meet every quarter to review each vendor's performance. Assistance of computers shall be obtained for the vendor rating as far as possible. Vendor's should be classified as class 'A', 'B' and 'C' based on their performance results. Future enquiries call not be sent to class 'C' vendors. A price preference of 5% to class 'A' and 2% to class 'B' vendors shall be accorded over the prices quoted by class 'C' vendors."

(iii) Critical Incidents Method

Evaluating vendors by this method requires that a record of events and occurrences related to the buyer-vendor relationship is maintained in each vendor's file. The data and comments recorded should be significant, not trivial. They ought to reflect positive and negative aspects of actual performance. This kind of documentation can be used as a basis for discussing ways and means of overcoming difficulties, improving performance, acknowledging the existence of good business relationships, determining the competence of a vendor, and if necessary, considering termination. Because the critical incidents method is relatively easy to implement, it is particularly useful for small organizations.

(iv) Checklist System

Some companies use a simple check list to evaluate their vendors. Designed to facilitate vendor rating from the stand point of financial strength, size, product service, price, quality and the like, the check system is quite useful to evaluate suppliers.

3.3 STORES MANAGEMENT

3.3.1 Functions of Stores

Q8. What is stores. State the functions of stores.

(OR)

Explain the functions of stores.

Ans :

Stores is defined as supplies of goods. And storage is defined as the act of storing the goods. Some people use the term store-keeping which has the same meaning as storage.

In popular usage the term stores is used to cover all aspects of preservation of goods i.e., building, supplies and the act of storing.

Stores or storage is the function of receiving, storing and issuing materials. It involves supervision or the clearance of incoming supplies, to ensure that they are maintained good condition, safely and in readiness for use when required while they are in storage and issuing them against authorized requisitions. In short, it is connected with the physical handling and well-being of the stocks.

It should be mentioned that stores is not meant for stocking purchased materials alone Partly-finished goods, finished goods, spares, and consumables stores are also kept in stores. The emphasis here is on the storing of incoming materials.

Functions

The functions of stores may be listed as follows:

1. To receive raw materials and account for them.
2. To provide adequate and proper storage and preservation to the various items.

3. To meet the demands of the consuming departments by proper issues and account for the consumption.
4. To minimize obsolescence, surplus and scrap through proper codification, preservation and handling.
5. To highlight stock accumulation, discrepancies and abnormal consumption and effect control measures.
6. To ensure good housekeeping so that materials handling, materials preservation, stocking receipt and issue can be done adequately.
7. To assist in verification and provide supporting information for effective purchase action.

Q9. What is store management? Explain the functions of store management?

Ans : **(Dec.-20)**

According to Maynard responsibilities of store management are "to receive materials, to protect them while in storage from damage or unauthorized removal, to issue materials in the right quantities, at the right time, to the right place, and to provide these services at the least cost. "

Functions of Scientific Store Management

The working of store need to be organized to perform the following functions :

i) Requisitioning from purchasing department an economical quantity of material for delivery at the most appropriate time.

ii) Exercising control on quantity of materials received.

iii) Storing and protecting materials against hazardous condition, weather, deterioration and pilferage.

iv) Issuing materials against properly authorized material requisitions.

v) Maintaining exact records of all receipts, issues and balances to facilitate ordering of required materials.

vi) Maintaining adequate records of receipts and expenditures.

vii) Maintaining adequate stocks of materials to serve production needs,

viii) Keeping inventory investment within desired limits.

Q10. What are the objectives of stores management?

Ans :

1. To protect the goods available in storage against the losses
2. To provide low cost services of store keeping to the sales and manufacturing department.
3. To make the goods available for on time delivery.
4. To maintain the required in adequate quantities.
5. To ensure that the facilities of storage are located near the operating department.

3.3.2 Materials Control

Q11. Define Material Control. List out the objectives of Material Control.

Ans :

Material is an important resource for production process. Ensuring the availability of right quality of material in right quantity at right place at right time and at the right investment is material control.

Objectives

The following are the objectives of material control,

1. To ensure continuous supply of materials.
2. To avoid making excessive investment in materials.
3. To reduce the wastage of materials.
4. To follow an effective issue method of materials for reducing the risk of spoilage and obsolescence.

5. To maintain accurate information about the availability of materials.
6. To avoid misappropriation of materials.
7. Tomainta' reliability in the payment of amount to suppliers.

Q12. What are the functions of material control?

Ans : **(Dec.-19)**

Functions

Material management is a function responsible for coordinating, planning, sourcing, purchasing, moving, storing and controlling materials in an optimum manner so as to provide a pre-decided service to the customer at minimum cost.

Material management in any industry is primarily concerned with materials planning, supply, storage and control of incoming materials costs. It is concerned with activities involved in purchasing, storage, flow of materials which are directly employed in production and marketing of the finished goods.

The various functions of material control are

i) Materials Planning and Control

Based on the sales forecast and production plans, the materials planning and control is done. This involves estimating individual requirements of parts, preparation of materials budget, forecasting levels of inventories, scheduling the orders and monitoring the performance in relation to production and sales. While preparing materials procurement plans, macro and micro factors are to be taken into consideration.

Macro Factors

Macro factors which effect the materials planning are price trends, business cycles and government policies. These factors are to be kept in mind for fixing levels of inventory while preparing materials plan.

Micro Factors

Micro factors like plant utilization, rejection rate, lead times, inventory levels seasonality of demand are to be taken into consideration at the time of preparing materials plan.

ii) Purchasing

Purchasing includes selection of sources of supply, finalization of terms of purchase, placements of purchase orders, follow up, maintaining smooth relationship with suppliers, approval of payment to suppliers, evaluating and rating of suppliers.

3.4 CLASSIFICATION, CODIFICATION, SIMPLIFICATION AND STANDARDIZATION OF MATERIALS

Q13. Define classification of material.

Ans : **(Dec.-19)**

According to ICMA, classification is defined as "the arrangement of items in a logical sequence having regard to their nature (subjective classification) or the purpose to be fulfilled (objective classification)".

In simple terms, classification can be defined as the process of arranging or classifying items in groups or subgroups based on the features of materials.

Q14. Explain the classification of stores?

Ans :

Classification of Stores

Functionally, stores are of five types :

1. Receiving store
2. Main store
3. Finished product store (Warehouse)
4. Special store
5. Scrap yard

1. **Receiving store** to perform activities necessary to exercise control on quality and quantity of purchased materials before they are

accepted and taken into stock. Receiving store may be sub-divided as under:

i) Inward store to keep incoming materials until they are accepted and taken into stock.

ii) Quarantine store to temporarily stock materials which are under dispute and require suppliers' (or transporters') certification (e.g. quantity discrepancy in the consignment, transit damage to the goods etc.)

iii) Rejection store to stock defective (non-conforming) items until they are sent back to their suppliers.

2. **Main store** to perform activities concerning storage and issue of accepted materials and maintenance of records. Main store may be either centralized and housed in a large godown or decentralized and located near the point of use of materials. Main store may be divided as under :

i) Crib store to stock cutting tools, hand tools, measuring instruments and gauges etc. to be issued to the workmen in the beginning of the shift and to be received at the end of the shift (or job).

ii) Finished part store to stock components and parts produced at works in economic lot sizes.

iii) Plant (or maintenance) store to stock spares of plant and machinery.

iv) Sub-store (raw materials store) to stock bar stocks, castings and forgings etc. which require lot of space and can be stocked in areas open to sky.

3. **Warehouse** (finished product store) to perform activities concerning receipt, packaging and packing, despatch of finished goods to different destinations and handling of connected papers and documents.

4. **Special stor**e to perform activities of receipt, storage and issue of special materials.

Typical examples of special stores are :

a) "Bonded store" to stock materials "hypothicated with banks", to stock "excisable goods", etc.

b) Statutory store to stock materials namely kerosene, diesel and other petroleum products requiring strict conformance to safety precautions stipulated as per statutory regulations.

c) "Temperature controlled store" to stock perishable items such as meat, fish, milk, vegetables and fruits or goods like rubber and rubber parts, active ingredients like antibiotics and vitamins, and others which require temperature controlled stores rooms.

5. Scrap yards to perform activities of receipt, segregation and storage of different types of scrapy.

Q15. What is codification of material? Describe the various methods of codification of material.

Ans : **(Dec.-19)**

Meaning

It is one of the functions of stores management. Codification is a process of representing each item by a number, the digit of which indicates the group, the sub-group, the type and the dimension of the item. Many organizations in the public and private sectors, railways have their own system of codification, varying from eight to thirteen digits. The first two digits represents the major groups, such as raw materials, spare parts, sub-contracted items, hardware items, packing material, tools, oil, stationery etc. The next two digits indicate the sub-groups, such as, ferrous, non-ferrous etc. Dimensional characteristics of length, width, head diameter etc. constitute further three digits and the last digit is reserved for minor variations.

Methods

The common code systems, among the many used for stores (materials) are given below:

1. Alphabetic system,
2. Simple numeric or sequence system,
3. Combination system,
4. Block system,

5. Decimal system,
6. Numerical system,
7. Mnemonic system and
8. Six letter – nine letter codes.

1. Alphabetic System

Letters are chosen to represent particular classification. Alphabet code has 26 letters. Each position in the code has 26 possible letters, where relatively few classification are involved, assignment of letter designates is sometimes arbitrarily made.

2. Simple Numeric or Sequence System

Numbers are assigned for classification. The obvious disadvantage of this simple numerical sequence is that there are no memory adds incorporated in the system. A good deal of time is wasted in aching for code numbers in materials code books.

3. Combination System

Some firms find it advantageous to combine a mnemonic and numerical or decimal system.

4. Block System

Blocks of numbers are reserved for specified classifications such as 1700-1799 for the raw materials and 1800-1899 for manufacturing parts, etc. The advantage by doing so is that wherever numbers are not assigned, subsequent expansion can be accommodated.

5. Decimal System

Numbers are assigned in such a manner that each digit represents a sub-group or sub-account of the previous digit. The principal advantage of a decimal system is its capacity to accommodate a new item. The disadvantage is that it becomes cumbersome when a basic unit has many minor assemblies which in turn consists of numerous sub-assemblies.

6. Numeric System

The first or basic numbers indicate specific classes with subsequent digits used to describe sub-classifications.

7. Mnemonic System

It is an alphabetic system designed with an objective of easy memorization.

8. Six Letter or Nine Letter Codes

This system is widely adopted and is of immense use.

Q16. What are the Advantages of Codification?

Ans :

To identify correctly, to avoid multiplication of items, to save time and labour, to facilitate easy location and proper functioning of the storehouse, a proper codification is to be evolved so as to obtain the following benefits:

1. To avoid long and unwieldy description.
2. To have accurate and logical identification.
3. To prevent duplication.
4. To standardize items.
5. To reduce varieties.
6. To have an efficient purchasing department.
7. To obtain efficiency in recording and accounting.
8. To simplify and facilitate mechanical recording.
9. To simplify and facilitate pricing.
10. To have proper system of location and indexing.
11. To assure correct and efficient inspection; and
12. To implement production as planned.

Q17. Explain the concept of simplification.

(OR)

What do you mean by simplification of materials?

Ans : **(Dec.-19)**

Simplification is the first step of standardization. It is the process which deals with minimizing different types of manufactured products. It helps in minimizing product range, assemblies, parts, materials and design.

Simplification is beneficial to manufacturers, suppliers and buyers. It carries out the advantages of reduced inventory, better plant utilization, greater use of storage space and reduction of buying/selling efforts to manufacturers. It makes suppliers to focus on the sale of fewer items. Thus, they can maximize their turnover. Finally buyers can experience better after sales service with this process of simplification followed by the manufacturers.

Simplification means elimination of superfluous varieties, sizes, dimensions, etc. Product simplification means reducing the number of varieties. The other names for simplification are unification or variety reduction.

Simplification will be advantageous to manufacturers, suppliers and buyers. Reduced inventory, better plant utilization, greater use of storage space, reduction of buying/selling efforts are the advantages to manufacturers. Suppliers can concentrate on the sale of fewer items and thereby increase their turnover. Buyers can have better after sales services due to the use of less number of parts. Simplification is the first step towards standardization.

Considerations in simplifying items

1. Can simplification be effectively achieved depending upon the nature of item?
2. How simplification will affect customer demand and volume of sale?
3. Does market competition permit simplification or it encourages product diversification?

Q18. Define Standardization. Explain the functions of Standardization.

(OR)

What do you mean by Standardization of materials?

Ans : **(Dec.-19)**

Standardization is a procedure in which rules are developed and used for a systematic approach to a specific activity with cooperation of all related parties in order to benefit and enhance the optimum overall economy by considering functional conditions and safety requirements. Standardization depends on the combined results of science, techniques and experience. It is not only emphasizing on the present but also focuses on future development'.

Standardization is a design activity which eliminates the variations among the group of products or parts. It results in the production of high quantity of each product which causes low production costs, improves the quality of product and reduces inventory and easy automation.

Functions

The functional classification of standardization is based on the following functions,

1. Units and Measurements

International system of units was developed to have single system of units which was summarized as S.I units. The primary S.I units comprise of six basic units two supplementary units and 27 derived units. Precision measurement is now considered as a distinct field of engineering known as Metrology. BIPM (Bureau International Des poids et Measures), an international authority was formed to sustain the measuring standards of physical quantities. International Organization of Legal Metrology was developed in 1956 to secure, safeguard and maintain the standards of units and measurement.

2. Grouping and Grading

In this, different varieties of products are grouped with specific grades based on their specification or end use. But for some products grouping and grading is done on the basis of dimensions or power rating.

3 Specification and Tolerance

While designing the products and processes, the standardization of specification and tolerance plays an important role Usually, specifications are of three types: Obligatory, Optional and Informative. Specifications are useful for legal, commercial and technical purposes and guides all the sections of society like manufacturers, traders and users.

4. Inspection and Sampling

In order to protect the interests of both the buyers and sellers and to have quality

assurances, standard of inspection and sampling are used. These standards reduce the costs by avoiding rework and by decreasing the number of defects.

5. Quality and Testing

Standards of Testing are needed for quality, uniformity and interchangeability of products which forms a part of specification. Testing is considered as the most essential factor of standardization which is done by measuring the given parameters.

6. Variety Reduction

Variety Reduction deals with reducing the number of products and processes along with the number of groups, grades and classes of those products, processes, materials and components. While reducing the variety, OR techniques are used along with discretion because if the restriction exceeds then it becomes counter productive and effects the consumer interest.

7. Packaging and Labelling

Packaging and Labelling are the essential part of standard specification. Packaging has now gained much importance and emerged as a separate discipline. Several efforts are made for attaining a uniform standard of labelling which helps the consumers. Labelling acts as a certificate of quality and quantity of contents. It has become compulsory to label the dangerous goods such as explosives etc.

8. Legal and Standard Practice (code)

When quality completely satisfies the consumers then it is termed as Total Quality Control (TQC). It deals with standardization of many activities both in legal aspects as well as in standard practices or code of conduct. Some legal aspects are agreement, termination, compensation for services rendered, modification of agreement etc. Standard practices (codes) involve both technical and non-technical areas like, safety of employees, wastage control, environmental protection, training and development etc., which need to be standardized.

9. Forms and Contracts

Contracts are an important element of agreement. It can be classified into technical, commercial or financial contracts. Standardization of contracts involves a lot of confusion as it makes use of different forms. The level of confusion increases in bilateral contracts which deal with different countries and different banks. "Sine qua non" is a type of standardization used in banking and commercial transactions for globalizing the industries and internationalizing the business.

Q19. What are the advantages and applications of standardization.

Ans :

Advantages

The advantages gained from standardization procedure are as listed below:

- Fewer specifications, drawings and part lists have to be prepared and issued.
- Better quality products.
- Lower unit costs.
- Increased margin of profit.
- Easy availability of spares.
- Minimum inventory cost.
- Quantity discounts are possible because of purchase of raw materials in large volume.

Application

Standardization can be applied to a major extent in the following 'fields:

- Finished products, e.g. cars and televisions.
- Sub-assemblies and components, e.g. automobile gearboxes and auto-electric bulbs.
- Materials, e.g. both direct materials (plain carbon and alloy steels, welding electrode, core wire, etc.) and indirect materials such as oils and greases.
- Production equipments, e.g. that of machine tools, press, welding equipments, etc.

3.5 Economic Order Quantity

Q20. Define Economic Order Quantity.

(OR)

Explain briefly about Economic Order Quantity.

Ans : **(Dec.-19)**

Economic Order Quantity (EOQ) refers to the amount to material to be ordered to make the best use of the firm's resources, taking into consideration factors such as shelf life of the material, space required and space available for warehousing, price breaks for ordering quantity etc.

Formula

$$EOQ = \sqrt{\frac{2AO}{C}}$$

where

A = Annual Consumption

O = Ordering Cost

C = Carrying Cost

The performance of the inventory system and the process of arriving at economic order quantity involves certain costs which are described as follows.

The various costs involved are,

(a) Purchase cost per unit

(b) Ordering cost per unit

(c) Holding cost per unit of time

(d) Shortage cost.

(a) Purchase Cost

The purchase cost consists of the actual price paid for procurement of items. The unit price is independent of the size of the quantity ordered or purchased.

(b) Ordering Cost

Ordering cost is associated with the cost of placing orders for procurement of items from outside suppliers or it can also be termed as setting cost if the items are produced by setting up of machinery. The cost per ordering generally includes,

(i) Requisition cost of handling of invoices, stationary, payments etc.

(ii) Cost of service which includes cost of mailing, telephone calls and other follow up actions.

(iii) Material handling costs incurred in receiving, inspection and storing of items included in the order.

Ordering cost is independent of the size of the order, rather it varies with the number of orders placed during a period of time. Thus if a large number of orders are placed, more money will be required for purchasing the items.

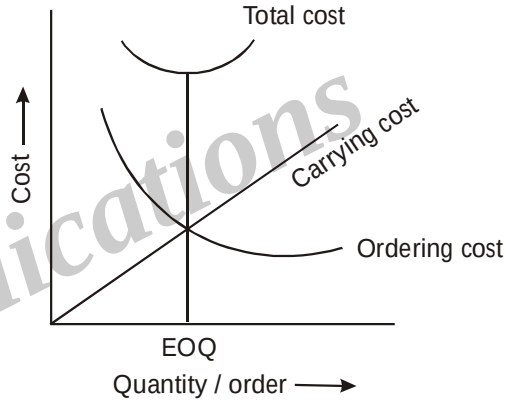


Fig. : Graphical Representation of Economic Order Quantity

(c) Holding Cost

It is also called carrying cost. It is associated with holding inventory carrying cost and is directly proportional to the order size. The factors are :

(i) Storage cost incurred for providing warehouse space to store the product.

(ii) Insurance charges against possible loss from fire or other forms of damage

(iii) Handling cost incurred by payment of salaries to employees for handling inventory.

(iv) Interest paid on investment.

(v) Obsolescence and deterioration costs incurred When parties of the inventory become obsolete or damaged, deteriorated by natural causes.

(d) Shortage Cost

It is also called storage cost. The storage of items is said to happen when actual demand cannot be fulfilled from existing stock of items. We can measure it in the form of goodwill loss and lost profit due to existing demand but non-availability of stock i.e., shortage of stock.

Q21. What are the assumptions of EOQ?

Ans :

The following are the assumptions of EOQ are :

1. Demand for the product is constant and uniform throughout the period.
2. Lead time (time from ordering to receipt) constant
3. Price per unit of product is constant
4. Inventory holding cost is based on average inventory
5. Ordering costs are constant, and
6. All demands for the product will be satisfied (no back orders are allowed).

Q22. Explain EOQ with Quantity Discount.

Ans :

When items are purchased in bulk, buyers are usually given discount in the purchase price of goods. This discount may be a step function of purchase quantity shown as.

Quantity	Purchase Price
$0 \le Q_1 < b_1$	P_1
$b_1 \le Q_2 < b_2$	P_2
$b_2 \le Q_3 < b_3$	P_3
.	.
.	.
.	.
$b_{n-1} \le Q_4$	P_n

The procedure to compute the optimal order size for this situation is given in the following steps.

Step 1 : Find EOQ for the nth (last) price break.

$$Q_n^* = \sqrt{\frac{2C_oD}{iP_n}}$$

If it is greater than or equal to b_{n-1}, then the optimal order size $Q^* = Q_n^*$; otherwise go to Step-2

Step 2 : Find EOQ for the n – 1th price break.

$$Q_{n-1}^* = \sqrt{\frac{2C_oD}{iP_{n-1}}}$$

If it is greater than or equal to b_{n-2}, then compute the following, and select least cost purchase quantity as the optimal order size; otherwise go to Step 3:

(i) Total cost, TC(Q^*_{n-1})

(ii) Total cost, TC(b_{n-1})

Step 3 : Find EOQ for the n – 2th price break.

$$Q^*_{n-2} = \sqrt{\frac{2C_oD}{iP_{n-2}}}$$

It is greater than or equal to b_{n-3}, then compute the following and select least cost purchase quantity; otherwise go to Step 4.

(i) Total cost, TC(Q^*_{n-2})

(ii) Total cost, TC(b_{n-2})

(iii) Total cost, TC(b_{n-1})

Step 4 : Continue in this manner until $Q^*_{n-i} \geq b_{n-i-1}$. Then compare total costs TC(Q^*_{n-i}), TC(b_{n-i}), TC(b_{n-i+1}), ..., TC(b_{n-1}) corresponding to purchase quantities Q^*_{n-i}, b_{n-1}, b_{n-i+1}, ..., b_{n-1}, respectively. Finally, select the purchase quantity w.r.t the minimum total cost.

Q23. Explain the method of determining the EOQ with a single price breaks.

Ans : **(Dec.-19)**

The purchase inventory model with one price break (one quantity discount) for determining EOQ is expressed as follows,

Range of Quantity	Purchase Cost (per unit)
$O \leq Q < b$	C_1
$b \leq Q$	C_2

'b' represents the quantity at which the discount is offered and $C_1 > C_2$

Optimal purchase quantity can be obtained with the help of following steps,

Steps-1

Determine the optimal order quantity for the lowest price (at highest discount) with the help of the following formula :

D = Annual demand

C_0 = Ordering cost

I = Annual Inventory carrying cost as a percent of unit cost.

$$Q^*_2 = \sqrt{\frac{2DC_0}{I \times C_2}}$$

Step-2

The value of Q^*_2 is compared with the quantity b which is needed for obtaining the discount.

Step-3

If $Q^*_2 \geq b$ then the orders for quantities for size Q^* are placed for availing discount and if $Q^*_2 < b$ proceed to step 4.

Step-4

Compute the optimal order quantity (Q^*_1) for price C_1 which is given $Q^*_1 = \sqrt{\frac{2DC_0}{I \times C_1}}$

Step-5

Compare the total costs for quantity Q^*_1 and quantity b.

$$TC\left(Q^*_1\right) = \frac{D}{Q^*_1}C_0 + \frac{Q_1}{2}\left(C_1 I\right) + DC_1$$

$$TC(b) = \frac{D}{b}C_0 + \frac{b}{2} \times \left(C_2 I\right) + DC_2$$

Step-6

(i) If $TC\left(Q^*_1\right) \geq TC(b)$, then the orders for quantities of size b is placed for availing the discount.

(ii) If $TC(Q^*_1) < TC(b)$, then order for Q^*_1

PROBLEMS

1. Calculate Economic Order Quantity (EOQ) from the following information:

Annual requirements	**1,350 units**
Cost of materials per units	**Rs. 32**
Cost of placing and receiving one order:	**Rs. 47/-**

Annual carrying cost for inventory value 8%; carrying cost is estimated at cost price of material.

Sol. **(Oct.-20)**

$$EOQ = \sqrt{\frac{2AO}{C}}$$

Where

A = Annual Consumption = 1350 units

O = Ordering cost = 47

$$C = \text{Carrying cost} = 32 \times \frac{8}{100} = 2.56$$

$$\sqrt{\frac{2\times1350\times47}{2.56}} = \sqrt{\frac{126900}{2.56}}$$

$= \sqrt{49570.31}$

= 223 units

2. Calculate Economic Order Quantity (EOQ) from the following :

Annual consumption 6,000 units

Cost of ordering ` 60

Carrying costs ` 2

Sol. **(Dec.-19)**

$$EOQ = \sqrt{\frac{2AO}{C}}$$

where,

A = Annual consumption = 6000 units

O = Ordering cost = 60

C = Carrying cost = 2

$$= \sqrt{\frac{2\times6000\times60}{2}} = \sqrt{\frac{120000}{2}} = \sqrt{360000}$$

= 600 units

3. From the following particulars, calculate the Economic Order Quantity (ECQ)

Annual requirements 1,600 units

Cost of materials per unit ` 40

Cost of placing and receiving one order ` 50

Annual carrying cost for inventory value 10%, carrying cost is estimated at cost price of materials.

Sol. **(Dec.-19)**

$$EOQ = \sqrt{\frac{2AO}{C}}$$

where,

A = Annual consumption = 1600 units

O = Ordering cost = 50

C = Carrying = $\frac{40\times10}{100}$ = 4

$$= \sqrt{\frac{2\times1600\times50}{4}} = \sqrt{\frac{160000}{4}} = \sqrt{40,000}$$

= 200 units

4. Alpha industry estimates that it will sell 12,000 units of its product for the forthcoming year. The ordering cost is ` 100 per order and the carrying cost per unit per year is 20 per cent of the purchase price per unit. The purchase price per unit is ` 50. Find

(a) Economic order quantity (EOQ)

(b) No. of orders per year

(c) Time between successive orders

Sol.

(a) A = 12,000 units/year

O = ` 100/order

C = ` 50 × 0.2

= ` 10/unit/year

Therefore,

$$EOQ = \sqrt{\frac{2AO}{C}}$$

$$= \sqrt{\frac{2\times100\times12000}{10}}$$

$$= \sqrt{2,40,000}$$

= 490 units (Approx).

(b) No. of order/year $= \frac{EOQ}{\text{No.of days in a year}}$

$$= \frac{12,000}{490} = 24.49$$

(c) Time between successive orders

= Q*/D = 490/12,000

= 0.04 year .48 month

5. A factory uses annually 24,000 units of raw material which cost Rs. 125 per unit placing each order costs Rs. 25 and carrying cost is 6% per year of the average inventory :

(i) Find out the economic order quantity

(ii) How many orders are to be placed in a year ?

Sol : **(July-19)**

(i) $EOQ = \sqrt{\frac{2AO}{C}}$

A = Annual Consumption = 24000

O = Ordering Cost = 25

C = 6% × 125 = 7.5

$= \sqrt{\frac{2 \times 24000 \times 25}{7.5}}$

$= \sqrt{1,60,000} = 400$

(ii) No. of orders placed in a year = $\frac{EOQ}{\text{No.of days in a year}} = \frac{400}{365} = 1.09$

---

6. A factory uses annually 24,000 units of raw material which cost Rs. 125 per unit placing each order costs Rs. 25 and carrying cost is 6% per year of the average inventory.

i) Find out the EOQ

ii) How many orders are to be placed in a year ?

Sol : **(Dec.-18)**

i) $EOQ = \sqrt{\frac{2AO}{C}}$

Where

A – Annual consumption = 24000 units

O – Ordering cost = 25 Rs.

C – Carrying cost = $125 \times \frac{6}{100} = 7.5$

$= \sqrt{\frac{2 \times 24000 \times 25}{7.5}}$

$= \sqrt{160000} = 400$

ii) No. of orders placed in a year = $\frac{EOQ}{\text{No.of days in a year}}$

$= \frac{400}{365} = 1.095$

3.6 Selective Inventory Control Techniques

Q24. What are the various techniques of Inventory Control?

(OR)

Explain various inventory control techniques in brief.

Ans : **(Dec.-20)**

1. Economic order quantity

Economic order quantity, or EOQ, is a formula for the ideal order quantity a company needs to purchase for its inventory with a set of variables like total costs of production, demand rate, and other factors.

The overall goal of EOQ is to minimize related costs. The formula is used to identify the greatest number of product units to order to minimize buying. The formula also takes the number of units in the delivery of and storing of inventory unit costs. This helps free up tied cash in inventory for most companies.

2. Minimum order quantity

On the supplier side, minimum order quantity (MOQ) is the smallest amount of set stock a supplier is willing to sell. If retailers are unable to purchase the MOQ of a product, the supplier won't sell it to you.

For example, inventory items that cost more to produce typically have a smaller MOQ as opposed to cheaper items that are easier and more cost effective to make.

3. ABC analysis

This inventory categorization technique splits subjects into three categories to identify items that have a heavy impact on overall inventory cost.

- Category A serves as your most valuable products that contribute the most to overall profit.
- Category B is the products that fall somewhere in between the most and least valuable.
- Category C is for the small transactions that are vital for overall profit but don't matter much individually to the company altogether.

4. Just-in-time

Just-in-time (JIT) inventory management is a technique that arranges raw material orders from suppliers in direct connection with production schedules.

JIT is a great way to reduce inventory costs. Companies receive inventory on an as-needed basis instead of ordering too much and risking dead stock. Dead stock is inventory that was never sold or used by customers before being removed from sale status.

5. Safety stock inventory

Safety stock inventory management is extra inventory being ordered beyond expected demand. This technique is used to prevent stockouts typically caused by incorrect forecasting or unforeseen changes in customer demand.

6. FIFO and LIFO.

LIFO and FIFO are methods to determine the cost of inventory. FIFO, or First in, First out, assumes the older inventory is sold first. FIFO is a great way to keep inventory fresh.

LIFO, or Last-in, First-out, assumes the newer inventory is typically sold first. LIFO helps prevent inventory from going bad.

7. Reorder point formula.

The reorder point formula is an inventory management technique that's based on a business's own purchase and sales cycles that varies on a per-product basis. A reorder point is usually higher than a safety stock number to factor in lead time.

8. Batch tracking

Batch tracking is a quality control inventory management technique wherein users can group and monitor a set of stock with similar traits. This method helps to track the expiration of inventory or trace defective items back to their original batch.

9. VED Analysis

VED analysis represents classification of items based on their criticality. The analysis classifies the items into three groups called Vital, Essential and Desirable. "Vital" category encompasses those items for want of which production would come to halt. "Essential" group includes items whose stakeouts cost is very high. And "Desirable" group comprises of items which do not cause any immediate loss of production or their stockout entail nominal expenditure and cause minor disruptions for a short duration.

10. FSN Analysis

FSN analysis is based on the frequency of use of the items in the stores. In this analysis, F stands for fast moving items, S stands for slow moving items and N stands for non-moving items. The fast moving items correspond to frequently used/issued items, the slow moving items correspond to less frequently issued/ used items and non-moving items correspond to the items which are not issued for longer period, say, 2 years.

The frequency of use of a fast moving item will be more than one in a month and that of a slow moving item will be less than one in a month. The frequency of use of a non-moving item will be zero during 2 year period.

This analysis will help the stores manager to design the stores layout such that the fast moving items are kept in the front portion of the stores so that such items are drawn very quickly while issuing them to the shop floor. Further, the information on the non-moving items will enable the management to take a decision whether it is required in future or to salvage them once for all. If such items are salvaged, the working capital position of the company will improve because the locked-up capital is eliminated. If the company wants to recycle this capital, it is made available to stock other items which are in active use.

11. XYZ Analysis

XYZ analysis is aimed to evaluate the fluctuations in demand or consumption of the items in the stores. For each item, coefficient of variation is computed and then the items are classified based on this coefficient as per the ratio of 20 per cent : 30 per cent :50 per cent : 50 per cent for X, Y and Z items, respectively.

12. SDE Analysis

SDE analysis is done based on the lead time required to procure the items. In this classification, S means scarce commodity, D stands for difficult to procure and E stands for easily available.

The items which are imported and those items which have more than 6 months lead time are grouped under S (Scarce) class. The items which have more than fortnight but less than 6 months lead time are grouped under D (Difficult) class. The items which have less than a fortnight lead time are grouped under E (Easily available) class. This analysis will help to reduce the lead time required for the vital items. The resultant benefit of this analysis is to avoid the stock outs of the items. If the lead time reduction is not possible for certain items, a suitable stocking policy may be established such that the total inventory cost is minimized and at the same time the other aspects like, criticality, movement, etc. are taken into account.

3.6.1 ABC Analysis

Q25. Explain briefly about ABC Analysis.

(OR)

What is ABC Analysis? Explain the procedure of ABC Analysis.

(OR)

Explain ABC Analysis techniques of inventory Management

(OR)

Discuss ABC analysis in detail.

(OR)

Discuss ABC approach of Inventory control system. What is the procedure followed in conducting ABC analysis.

Ans : **(Dec.-20, July-19, Dec.-18)**

ABC analysis is a technique which is used to classify the items in store based on the demand of the stock.

There may be variety of items that need to be purchased and stocked in advance for issuing the same to various production departments. One has to continuously monitor the stock according to the demand pattern of each item and issue the replenishment order. If the stock on hand of a particular item becomes less than or equal to its reorder level, immediately an order is to be placed for its economical quantity. It will be very difficult to continuously monitor the stock level of each item and place order on the above mentioned condition. Hence, it is highly essential to classify the items of the stores into different categories. Then it will be easy to apply tight control on selected categories.

ABC analysis is one such technique which classifies the items into A, B and C class items. The concept of this classification is illustrated in Figure.

From Figure below, it is clear that 10 per cent of the items accounts for 70 per cent of the annual consumption value of the items, 20 per cent of the items accounts for 20 per cent of the annual consumption value of the items and 70 per cent of the items accounts for 10 per cent of the annual consumption value of the items. These combinations are only ideal. In reality, it is very difficult to fix percentages simultaneously on number of items and annual consumption of items. Mainly, the percentages on the annual consumption of items will be used as a criterion for classifying the items into A, B and C classes.

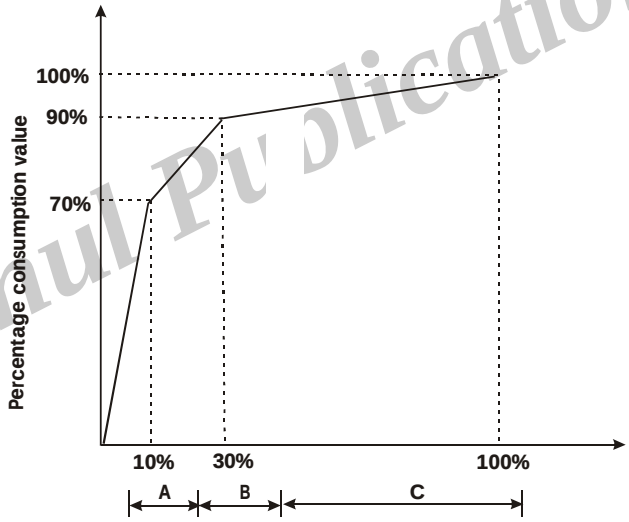


Fig.: Cumulative curve of ABC Analysis

Procedure

The steps of ABC analysis are presented below.

Step 1: Input the following.

- Total number of items.
- Item code, annual consumption in terms of units and unit price for each of the items.

Step 2: For each item, compute annual consumption value in terms of rupees by multiplying its annual consumption units with its unit price.

Step 3: Arrange the items and their details in descending order of the annual consumption values computed in Step 2.

Step 4: Compute cumulative values of the annual consumption values.

Step 5: Group the items into A, B and C classes by dividing the items into 70 per cent, 20 per cent and 10 per cent of the annual consumption values, respectively from top to bottom in the sorted list of Step 3.

Q26. State the advantages and disadvantages of ABC Analysis.

Ans :

Advantages

Some of the advantages of ABC analysis are as follows,

1. It facilitates selective control and thereby saves valuable time of executives.
2. It eliminates lot of unnecessary work involved in various control procedures.
3. It results in better and economic control of items in inventory.
4. It facilitates inventory control and control over usage of store materials which finally results in cost control.
5. By classifying inventory into ABC, it is also possible to reduce the investment in inventories.

Disadvantages

ABC analysis is considered as an effective technique for selective control. However it includes few limitations which are as follows,

1. Although ABC analysis is a fundamental tool for exercising selective control over various inventory items, it does not permit precise consideration of all relevant problem of inventory control.
2. If ABC analysis is not reviewed properly and updated periodically, the real purpose of control may not be furnished.

   For example, sea items, diesel, oil in a firm will become most high value items during crisis and hence requires more attention.
3. The periodic consumption value is considered as the basis for ABC classification, because of which ABC classification can disregard the requirements of spare parts the criticality of which is high, but the value of consumption is low.

PROBLEMS

7. From the following data draw an ABC analysis graph after classifying A, B & C class items.

Item	Unit price	Annual Consumption (units)
1	200.0	3,000
2	2.0	60,000
3	5000.0	20
4	12.5	200
5	9.0	350
6	25.0	6,000
7	1000.0	40
8	70.0	300

Sol :

Step No. 1 : Determination of annual consumption value.

Item	(Annual consumption (units) × Unit price (Rs.)]	Annual consumption value (Rs.) (ACV)
1	3000 × 200	6,00,000
2	60,000 × 2	1,20,000
3	20 × 5000	1,00,000
4	12.5 × 200	2,500
5	9 × 350	3,150
6	25 × 6000	1,50,000
7	1000 × 40	40,000
8	70 × 300	21,000

Step No. 2

Re-arrange the item in the descending order of annual consumption value and calculate cumulative ACV.

Item	(Annual consumption (units) × Unit price (Rs.)]	Annual consumption value (Rs.) (ACV)
1	6,00,000	6,00,000
6	1,50,000	7,50,000
2	1,20,000	8,70,000
3	1,00,000	9,70,000
7	40,000	10,10,000
8	21,000	10,31,000
5	3150	10,34,150
4	2500	10,36,650
	10,36,650	

Step No. 3

Since the basis for ABC classification is not given in the problem, assume the following basis.

Category	Percentage of total ACV
A	70
B	20
C	10

70% of total ACV = 0.70 × 10,36,650 = 7,25,655

Since this value is near to cumulative ACV of Rs. 7,50,000, categorize items 1 and 6 under 'A' category.

(A + B) together account for 90% of ACV.

90% ACV = 0.9 × 10,36,650 = Rs. 9,32,985

since this value is nearer to cumulative ACV of Rs. 9,70,000 categorize items 2 and 3 under 'B' category. The remaining items, 7, 8, 5 and 4 are categorized under 'C' category.

Step 4

Construction of ABC analysis graph

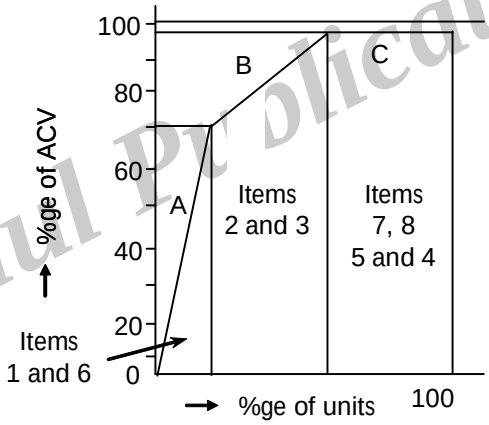
$$\left.\begin{matrix}\text{Exact \%age of ACV of} \\ \text{'A' category items}\end{matrix}\right\} = \frac{7,50,000}{10,36,650} \times 100 = 72.34\%$$

$$\text{Exact \% age of (A + B) items} = \frac{9,70,000}{10,36,650} \times 100 = 93.57\%$$

$$\text{Exact \% age of (A + B) items} = \frac{9,70,000}{10,36,650} \times 100 = 93.57\%$$

% age of ACV of 'B' item = 93.57 – 72.34 = 21.23%

% age of ACV of 'C' item = 100 – 93.57 = 6.43%



8 The following data is available on consumption pattern of certain materials in an organization.

Group	No. of Items	Monthly consumption (units)	Price Item (Rs.)
I	40	3000	9
II	20	270	100
III	100	1700	5
IV	200	1500	4
V	60	340	50
VI	300	2500	1
VII	250	2000	2
VIII	30	170	500

Find out A, B, C items when

'A' item account for 85% of consumption value.

'B' item account for 10% of consumption value.

'C' item account for 5% of consumption value.

Sol :

Step No. 1

Calculation of Monthly Consumption Value (MCV)

Group	No. of Items per group	Monthly consumption (units)	Unit price (Rs.)	Monthly consumption value (MCV)
I	40	300	90	10,80,000
II	200	270	100	5,40,000
III	100	1700	5	8,50,000
IV	200	1500	4	12,00,000
V	60	340	50	10,20,000
VI	300	2500	1	7,50,000
VII	250	2000	2	10,00,000
VIII	30	170	500	25,50,000
			Total	89,90,000

Step No. 2

Rearrange the groups in the decreasing order of MCV and calculate cumulative MCV for each group.

Group	MCV in descending order (Rs.)	Cumulative MCV (Rs.)	
VIII	25,50,000	25,50,000	
IV	12,00,000	37,50,000	
I	10,80,000	48,30,000	
V	10,20,000	58,50,000	
VII	10,00,000	68,50,000	
III	8,50,000	77,00,000	
VI	7,50,000	84,50,000	B Category
II	5,40,000	89,90,000	C Category

Step No. 3

Classifying the group as A, B & C based on MCV

85% of total MCV = 0.85 × 89,90,000 = 76,41,500

Since this value is nearer to cumulative MCV of 77,00,000 the groups VIII, IV, V, VII and III are categorized under group 'A'

(A + B) Comprise 95% of MCV

95% of MCV = 0.95 × 89,90,000 = Rs. 85,40,500

Since this value is nearer to 84,50,000 groups VI is under category 'B' and group II is under category 'C'.

9. A company uses 12 different items in the manufacturing process. Their annual requirement and unit costs are given as follows,

Items	Quantity	Unit Cost
1	9,000	10
2	300	750
3	5,400	210
4	3,800	90
5	12,400	10
6	90	1,200
7	600	400
8	22,000	2
9	750	175
10	1,000	250
11	7,600	75
12	10,000	4

Apply ABC analysis and give a graphical presentation.

Sol :

Step 1

Calculation of annual consumption value of given items in rupees.

Items Quantity	Annual demanded	unit Total Cost (f) Consumption	Cost or Annual Value
1	9,000	10	90,000
2	300	750	2,25,000
3	5,400	210	11,34,000
4	3,800	90	3,42,000
5	12,400	10	1,24,000

6	90	1,200	1,08,000
7	600	400	2,40,000
8	22,000	2	44,000
9	750	175	1,31,250
10	1,000	250	2,50,000
11	7,600	75	5,70,000
12	10,000	4	40,000

Step 2

Rearrange the items in the descending order of Annual Consumption Value (ACV) and calculate cumulative value of ACV

Table 2

Item No.	Annual Consumption Value (ACV) in Descending Order (Rs.)	Cumulative Value of ACV (`)
3	11,34,000	11,34,000
11	5,70,000	17,04,000
4	3,42,000	20,46,000
10	2,50,000	22,96,000
7	2,40,000	25,36,000
2	2,25,000	27,61,000
9	1,31,250	28,92,250
5	1,24,000	30,16,250
6	1,08,000	31,24,250
1	90,000	32,14,250
8	44,000	32,58,250
12	40,000	32,98,250
Total	**32,98,250**	

Step 3

Since the basis for ABC classification is not given in the problem assume the following basis.

Table 3

Category	Percentage of total ACV
A	70%
B	20%
C	10%

i.e., 70% of total ACV is consumed by category 'A' items, 20% of ACV is consumed by category 'B' items and 'C' category items constitute 10% of the total ACV.

For category A,

70% of total ACV = 70% of `. 32,98,250

$$= \frac{70}{100} \times 32,98,250$$

= `. 23,08,775.

Since this value is nearer to cumulative ACV of `. 25,36,000. Thus, the items 3, 11,4, 10 and 7 fall under the category 'A'.

Category (A+B) together accounts for 90% of ACV

= 90% of `. 32,98,250

$$= \frac{90}{100} \times 32,98,250 = \text{`. } 29,68,425$$

Since, this value is nearer to cumulative value of ACV of 30,16, 250, therefore categorized item 2, 9 and 5 come under the category 'B'.

The remaining items 6, 1, 8 and 12 are finally categorized under 'C' category.

Step 4

Construction of ABC analysis graph

Exact percentage of ACV of 'A' Category items

$$= \frac{25,36,000}{32,98,250} \times 100 = 76.89\%.$$

Percentage of (A+B) items

$$= \frac{30,16,250}{32,98,250} \times 100 = 91.45\%.$$

Expected percentage of ACV of 'B' category items

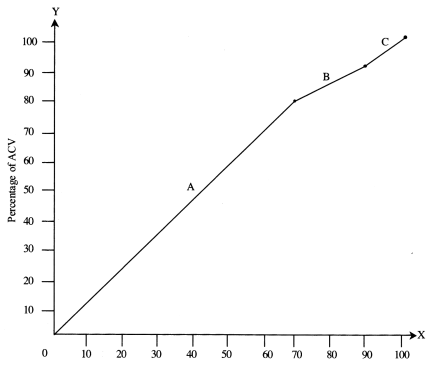
= (A+B)% – A%

= 91.45 -76.89

= 14.56%.

Expected percentage of ACV of 'C' category items

= 100 – 91.45 = 8.55%.



3.6.2 VED Analysis

Q27. Explain briefly about VED Analysis.

(OR)

What is VED Analysis. Explain the three categories of VED Analysis.

(OR)

What is VED analysis ? Explain the importance of VED analysis controlling the inventory.

Ans : **(Dec.-20, Dec.-19, Dec.-18)**

VED analysis represents classification of items based on their criticality. The analysis classifies the items into three groups called Vital, Essential and Desirable. "Vital" category encompasses those items for want of which production would come to halt. "Essential" group includes items whose stakeouts cost is very high. And "Desirable" group comprises of items which do not cause any immediate loss of production or their stockout entail nominal expenditure and cause minor disruptions for a short duration.

VED (Vital-Essential L-Desirable) analysis is carried out to identify critical items. An item which usagewise belongs to C-category may be critical from production point of view if its stockout can cause heavy production loss.

An item may be vital for a number of reasons, namely

- if the non-availability of the item can cause serious production losses.
- lead time for procurement is very large.
- it is non-standard item and is procured to buyer's design.
- the sources of supply is only one and is located far off from the buyer's plant.

Steps involved in making VED analysis are as under :

(i) Identify the factors to be considered for VED analysis. The commonly considered factors are : effect on production (i.e. stock out cost in the event of its non-availability), lead time, nature of the item and sources of supply.

(ii) Assign points/weightages to the factors according to their importance to the company. Typical examples of the weightages to the above four factors may be 30,30,20 and 20 points.

(iii) Divide each factor into three degrees and allocate points to each degree. Usually, the first degree is assigned points equal to the weightage of its factor; second degree is allocated points equal to twice the weightage of the factor and third degree is assigned points equal to thrice the weightage of the factor.

(iv) Prepare categorization plan (Table) which provides the basis of classification of items into vital, essential and desirable categories.

(v) Evaluate items one by one against each factor and assign points to the item depending upon the extent of presence of the factor in the item.

(vi) Place the items into V, E and D categories depending upon the points scored by them (Table 29.3) and basis of classification set under step (iv).

S.No.	Factor	First degree	Second degree	Third degree
1.	Stockout cost in the event of non-availability (30)	Above Rs. x (30)	Between Rs. x to y (60)	Above Rs. y (90)
2.	Lead time for procurement (30)	1 -4 weeks (30)	4-8 weeks (60)	Over 8 weeks (90)
3.	Nature of the item (20)	Produced to commercial standard, or off the shelf availability (20)	Produced to suppliers' design (40)	Produced to buyer's design or proprietary items (60)
4.	Sources of supply (20)	Local (20)	Outstation (40)	Imported, quota items i.e. controlled supply (60)

Table : Typical VED analysis categorization plan

Points	Classification
100-160	Desirable
161-230	Essential
231-300	Vital

Table : Typical categorization plan

VED analysis is best suited for spares inventory. In fact, it is advantageous to use more than one method, e.g. ABC and VED analysis together would be helpful for inventory control of spares.

Q28. What are the differences between ABC and VED analysis ?

Ans :

ABC Analysis	VED Analysis
1) In ABC analysis, the items are grouped depending on consumption value of the item.	1) In VED analysis, the items are grouped depending on their critical nature in the production.
2) The items in ABC analysis are classified in three categories i.e., A,B and C. A items have high annual consumption and B lies in between A and C.	2) The items in VED analysis are also classified into three categories i.e., V, E and D. V - items are extremely critical whereas D-items are not critical and E lies somewhere in between V and D.
3) These items are classified in descending order based on their control usage value.	3) These items are classified based on their criticality in production.
4) Service levels of inventory in ABC analysis increase from A to C	4) Service levels of inventory in VED analysis increase from D to V.

3.6.3 FSND Analysis

Q29. Explain briefly about FSND Analysis.

(OR)

Explain the concept of FSN Analysis

Ans : **(Dec.-20)**

FSN stand for fast moving, slow moving and non-moving. Here, classification is based on the pattern of issues from stores and is useful in controlling obsolescence.

To carry out FSN analysis, the date of receipt or the last date of issue, whichever is later, is taken to determine the number of months which have lapsed since the last transaction. The items are usually grouped in periods of 12 months.

FSN analysis is helpful in identifying active items which need to be reviewed regularly and surplus items which have to be examined further. Non-moving items may be examined further and their disposal can be considered.

3.6.4 XYZ Analysis

Q30. Explain briefly about XYZ Analysis.

Ans : **(Dec.-20)**

This classification is based on the value of inventory of materials actually held in stores at a given time (usually during stock checking annually or half-yearly). XYZ analysis helps to control average inventory value by focussing efforts to reduce the inventory of 'X' items which are usually 10% of the number of items stored, but accounting for 70% of the total inventory value. Similarly, 'Y' items are 20% of the number of items stored and account for 20% of the total inventory value. The remaining 70% of the items accounting for 10% of the total inventory value are 'Z' items. The XYZ classification is done in the same way as ABC analysis, the difference being the actual inventory value of items in stores instead of their estimated annual, consumption value.

Exercises Problems

1. A firm has several items of inventory. The average number of each of these items as well as their unit costs are listed below :

Item No.	Average Inventory Units	Average Cost per Unit (Rs)
1	5000	1.50
2	250	10.00
3	450	2.40
4	2000	17.50
5	25	200.00
6	20	160.00
7	300	6.00
8	200	70.00
9	3000	3.00
10	1500	2.50
11	5000	10.00
12	1800	2.20
14	4500	4.00
15	800	1.20

Classify these items as XYZ on the basis that,

X items account for 80% of total inventory value

Y items account for 15% of total inventory value

Z items account for 5% of total inventory value

2. From the following data, classify A, B, & C class items :

Item No.	Unit Price (Rs.)	Annual Consumption (units)
1	200	3,000
2	2	60,000
3	5000	20
4	12.5	200
5	9	35
6	25	6,000
7	1000	400

8	70	300
9	10	1,000
10	5	9,000
11	30	101
12	1000	1

3. Following details are known for a group of items

Group No.	No. of Items Group	Average Weekly Consumption/item	Price per Item (Rs.)
I	310	16	4
II	50	5	10
III	50	390	15
IV	240	6	2
V	50	10	8
VI	50	200	10
VII	125	55	5
VIII	125	25	14

Find out A, B & C items on the assumption that

'A' items account for 80% of the total consumption value

'B' items account for 15% of the total consumption value

'C' items account for 5% of the total consumption value

Calculate the actual percentage of A, B & C items to the total consumption value.

Short Question and Answers

1. ABC Analysis.

Ans :

ABC analysis is a technique which is used to classify the items in store based on the demand of the stock.

There may be variety of items that need to be purchased and stocked in advance for issuing the same to various production departments. One has to continuously monitor the stock according to the demand pattern of each item and issue the replenishment order. If the stock on hand of a particular item becomes less than or equal to its reorder level, immediately an order is to be placed for its economical quantity. It will be very difficult to continuously monitor the stock level of each item and place order on the above mentioned condition. Hence, it is highly essential to classify the items of the stores into different categories. Then it will be easy to apply tight control on selected categories.

2. VED Analysis.

Ans :

VED analysis represents classification of items based on their criticality. The analysis classifies the items into three groups called Vital, Essential and Desirable. "Vital" category encompasses those items for want of which production would come to halt. "Essential" group includes items whose stakeouts cost is very high. And "Desirable" group comprises of items which do not cause any immediate loss of production or their stockout entail nominal expenditure and cause minor disruptions for a short duration.

VED (Vital-Essential L-Desirable) analysis is carried out to identify critical items. An item which usagewise belongs to C-category may be critical from production point of view if its stockout can cause heavy production loss.

An item may be vital for a number of reasons, namely

- If the non-availability of the item can cause serious production losses.
- lead time for procurement is very large.
- it is non-standard item and is procured to buyer's design.
- the sources of supply is only one and is located far off from the buyer's plant.

3. Economic Order Quantity.

Ans :

Economic Order Quantity (EOQ) refers to the amount to material to be ordered to make the best use of the firm's resources, taking into consideration factors such as shelf life of the material, space required and space available for warehousing, price breaks for ordering quantity etc.

Formula

$$EOQ = \sqrt{\frac{2AO}{C}}$$

where

A = Annual Consumption

O = Ordering Cost

C = Carrying Cost

4. What is Purchase Management?

Ans :

Purchasing management refers to the effective management of raw materials/inputs purchased for manufacture infinished goods. Purchasing management basically aims at purchasing appropriate raw materials and other items and reducing costs to the maximum extent. Specific features of purchasing management includes,

- Ensuring continuous supply of raw materials/ inputs.
- Purchasing appropriate inputs at right time, right price and in right quantity and quality.
- Analyzing suppliers market and selecting best suitable vendor.

5. What is Vendor Rating?

Ans :

Meanings

Vendor rating is a continuous management process used for the assessment of vendors. It is engaged in measuring, evaluating and improving the supplier performance which helps the firm in making future sourcing decisions.

Factors

The following are the factors determining the vendor rating.

1. Price

Price is one of the most important consideration while making any type of purchases. Price is the major factor, which is observed keenly by any firm before making purchases.

2. Quick Delivery

Normally, companies prefer only those vendors (suppliers) who provide quick delivery or, on time delivery of products. Supplying firms can provide this facility to the companies by maintaining the stock in the form of warehousing.

3. Inventory Plans

Suppliers should make plans for storing the stock as this enables them to accept the proposals and deliver the products at right time. Effective planning of inventory and its storage by suppliers usually increases demand for their products and enables efficient delivery system.

6. Define Material Control. List out the objectives of Material Control.

Ans :

Material is an important resource for production process. Ensuring the availability of right quality of material in right quantity at right place at right time and at the right investment is material control.

Objectives

The following are the objectives of material control,

1. To ensure continuous supply of materials.
2. To avoid making excessive investment in materials.
3. To reduce the wastage of materials.
4. To follow an effective issue method of materials for reducing the risk of spoilage and obsolescence.
5. To maintain accurate information about the availability of materials.
6. To avoid misappropriation of materials.
7. Tomainta' reliability in the payment of amount to suppliers.

7. Define classification of material.

Ans :

According to ICMA, classification is defined as "the arrangement of items in a logical sequence having regard to their nature (subjective classification) or the purpose to be fulfilled (objective classification)".

In simple terms, classification can be defined as the process of arranging or classifying items in groups or subgroups based on the features of materials.

8. Advantages of Codification?

Ans :

1. To avoid long and unwieldy description.
2. To have accurate and logical identification.
3. To prevent duplication.
4. To standardize items.
5. To reduce varieties.
6. To have an efficient purchasing department.
7. To obtain efficiency in recording and accounting.
8. To simplify and facilitate mechanical recording.
9. To simplify and facilitate pricing.

9. Simplification.

Ans :

Simplification is the first step of standardization. It is the process which deals with minimizing different types of manufactured products. It helps in minimizing product range, assemblies, parts, materials and design.

Simplification is beneficial to manufacturers, suppliers and buyers. It carries out the advantages of reduced inventory, better plant utilization, greater use of storage space and reduction of buying/selling efforts to manufacturers. It makes suppliers to focus on the sale of fewer items. Thus, they can maximize their turnover. Finally buyers can experience better after sales service with this process of simplification followed by the manufacturers.

Simplification means elimination of superfluous varieties, sizes, dimensions, etc. Product simplification means reducing the number of varieties. The other names for simplification are unification or variety reduction.

10. Define Standardization.

Ans :

Standardization is a procedure in which rules are developed and used for a systematic approach to a specific activity with cooperation of all related parties in order to benefit and enhance the optimum overall economy by considering functional conditions and safety requirements. Standardization depends on the combined results of science, techniques and experience. It is not only emphasizing on the present but also focuses on future development'.

Standardization is a design activity which eliminates the variations among the group of products or parts. It results in the production of high quantity of each product which causes low production costs, improves the quality of product and reduces inventory and easy automation.

11. FSND Analysis.

Ans :

FSN stand for fast moving, slow moving and non-moving. Here, classification is based on the pattern of issues from stores and is useful in controlling obsolescence.

To carry out FSN analysis, the date of receipt or the last date of issue, whichever is later, is taken to determine the number of months which have lapsed since the last transaction. The items are usually grouped in periods of 12 months.

FSN analysis is helpful in identifying active items which need to be reviewed regularly and surplus items which have to be examined further. Non-moving items may be examined further and their disposal can be considered.

12. XYZ Analysis.

Ans :

This classification is based on the value of inventory of materials actually held in stores at a given time (usually during stock checking annually or half-yearly). XYZ analysis helps to control average inventory value by focussing efforts to reduce the inventory of 'X' items which are usually 10% of the number of items stored, but accounting for 70% of the total inventory value. Similarly, 'Y' items are 20% of the number of items stored and account for 20% of the total inventory value. The remaining 70% of the items accounting for 10% of the total inventory value are 'Z' items. The XYZ classification is done in the same way as ABC analysis, the difference being the actual inventory value of items in stores instead of their estimated annual, consumption value.

13. Decision making.

Ans :

Decision-making is an integral part of modern management. Essentially, Rational or sound decision making is taken as primary function of management. Every manager takes hundreds and hundreds of decisions subconsciously or consciously making it as the key component in the role of a manager. Decisions play important roles as they determine both organizational and managerial activities. A decision can be defined as a course of action purposely chosen from a set of alternatives to achieve organizational or managerial objectives or goals. Decision making process is continuous and indispensable component of managing any organization or business activities. Decisions are made to sustain the activities of all business activities and organizational functioning.

Decisions are made at every level of management to ensure organizational or business goals are achieved. Further, the decisions make up one of core functional values that every organization adopts and implements to ensure optimum growth and drivability in terms of services and or products offered.

Choose the Correct Answers

1. Cost control is a _____ action. [b]
   (a) Corrective action (b) Preventive action
   (c) Measurable action (d) All the above
2. _____ is defined as the time which is required to move orders in the production process from receipt to delivery. [c]
   (a) Variability (b) Throughput
   (c) Lead time (d) Waste management
3. The major role of vendors include the following, [b]
   (a) Maintaining input and output
   (b) Improving productivity and production plan
   (c) Improving profit margins
   (d) Increasing inventory cost
4. Which of the following analysis is used for cost reduction? [a]
   (a) Value analysis (b) Vendor analysis
   (c) EOQ Analysis (d) Performance analysis
5. One of the stages of source selection is, [d]
   (a) Deciding (b) Product assortment
   (c) Vendor management (d) Rating
6. Safety stock is calculated by using which of the following formula? [a]
   (a) Safety Stock = (Maximum Lead Time - Normal Lead Time) × Monthly Consumption
   (b) Safety Stock = (Minimum Lead Time - Normal Lead Time) × Monthly Consumption
   (c) Safety Stock = (Maximum Lead Time - Normal Lead Time) × Annual Consumption
   (d) Safety Stock = (Maximum Stock Level - Minimum Stock Level) × Per Day Consumption
7. _____ is the process which deals with minimizing different types of manufactured products. [c]
   (a) Classification (b) Codification
   (c) Simplification (d) Standardization.
8. In VED analysis, inventory items are categorized on the basic of what? [d]
   (a) Unit cost (b) Consumption rate
   (c) Annual consumption value (d) Criticality of the items.
9. In analysis, the inventory items are categorized on the basis of consumption. [d]
   (a) ABC analysis (b) XYZ analysis
   (c) SDE analysis (d) FNSD analysis.

10. _____ analysis approach is usually applied for categorizing the spare parts. [b]

(a) XYZ analysis (b) VED analysis

(c) FSND analysis (d) SED analysis

11. In operations management, classification of materials are categorized into [a]

(a) ABC analysis and VED analysis (b) VED analysis and FSND analysis

(c) SDE analysis and XYZ analysis (d) None of the above.

12. The deterministic models of inventory are [c]

(a) Purchase models with and without shortages

(b) Manufacturing models with and without shortages

(c) Both (a) and (b)

(d) None of the above

13. The techniques for stores management includes [d]

(a) Receiving and checking (b) Issue and dispatch

(c) Stock records (d) All the above.

14. Probabilistic models of inventory consists of [d]

(a) Fixed order quantity system (b) Fixed period quantity system

(c) Hybrid system (d) Only (a) and (b)

Fill in the blanks

1 _____ is a place where inventory items or materials are preserved.

2. The procedure followed for categorizing the items in XYZ analysis is same as analysis.

3. The fixed order quantity in Q-system is regarded as _____.

4. Safety stock is also known as _____.

5. The record maintained for showing quantitative receipts and issue of materials is called as _____.

6. Fixed order quantity system is also known as _____.

7. ABC analysis was developed on the basis of the _____.

8. In ABC analysis, ABC stands for _____.

9. _____ acts as a means for quality assurance and acceptance sampling.

10. Material requisition is also known as _____.

ANSWERS

1. Store
2. ABC Analysis
3. Economic Order Quantity (EOQ)
4. Buffer Stock
5. Bin Card
6. Q-System
7. Pareto's principle
8. Always Better Control
9. Vendor rating system.
10. Stores requisition

UNIT IV

INTRODUCTION TO OR :

Introduction to Operation Research: Introduction, Nature, Managerial applications and limitations of OR. Types of Operation Research Models. Linear Programming: Mathematical model, Formulation of LPP, assumptions underlying LPP, Solution by Graphical Method.

4.1 Introduction to Operation Research

Q1. Define the term Operation Research.

(OR)

Explain the meaning of Operation Research.

(OR)

What is Operation Research ?

Ans :

Introduction

The term, operations research was first coined in 1940 by McClosky and Trefthen in a small town Bowdsey, of the United Kingdom. This new science came into existence in a military context. During world war II, military management called on scientists from various disciplines and organized them into teams to assist in solving strategic and tactical problems, relating to air and land defence of the country.

Hence OR can be associated with "an art of winning the war without actually fighting it."

Definitions

1. **According to Morse and Kimbal (1946)** OR is a scientific method of providing executive departments with a quantitative basis for decision regarding the operations under their control.
2. **According to P.M.S. Blackett (1948)** OR is a scientific method of providing executive with an analytical and objective basis for decisions.
3. **According to P.M. Morse (1948)** The term 'OR' has hitherto-fore been used to connate various attempts to study operations of war by scientific methods. From a more general point of view, OR can be considered to be an attempt to study those operations of modern society which involved organizations of men or of men and machines.
4. **According to Churchman, Acoff, Aritoff (1957)** OR is the application of scientific methods, techniques and tools to problems involving the operations of systems so as to provide these in control of the operations with optimum solutions to the problem.
5. **According to T. L .Saaty (1958)** OR is the art of giving had answers to problems to which otherwise worse answers are given.
6. **According to Jagjit Singh (1968)** OR is a management activity pursued in two complementary ways one half by the free and bold exercise of commonsense untrammelled by any routine, and other half by the application of a repertoire of well established precreated methods and techniques.
7. **According to Operations Research Quarterly (1971)** OR is the attack of modern methods on complex problems arising in the direction and management to large systems of men, machines, materials, and money in industry, business and defence. The distinct of approach is to developed a scientific model of the system, incorporating measurements of factors such as chance and risk with which to predict and compare the outcomes of alternative decisions, strategies

or controls. The purpose is to help management to determine its policy and actions scientifically.

8. **According to** Operations Research is the art of winning war without actually fighting it.

9. **According to Miller and Starr.** OR is an applied decision theory. It uses any scientific mathematical or logical means to attempt to cope with the problems that confront the executive when he tries to achieve a through going rationality in dealing with his decision problems.

10. **According to H.M. Wagner** OR is a scientific approach to problem solving for executive management.

11. **According to C.Kittel** OR is an aid for the executive in making his decisions by providing him with the needed quantitative information based on the scientific method of analysis.

12. **According to E.L Arnoff & M.J. Netzorg** OR is the systematic method oriented study of the basic structure, characteristics, functions and relationships of an organization to provide the executive with a sound, scientific and quantitative basis for decision making.

13. **According to Fabrycky and Torgersen** OR is the application of scientific methods to problems arising from operations involving integrated systems of men, machines and materials. It normally utilizes the knowledge and skill of an inter-disciplinary research team to provide the managers of such systems with optimum operating solutions.

14. **According to OR Society of America** OR is an experimental and applied science devoted to observing, understanding and predicting the behaviour of purposeful man-machine systems and OR workers are actively engaged in applying this knowledge to practical problems in business, government, and society.

15. **According to Ackoff & Sasieni, (1968)** OR is the application of scientific method by inter-disciplinary teams to problems involving the controls of organized (man-machine) systems so as to provide solutions which best serve the purpose of the organization as a whole.

16. **According to Thieanfand Klekamp (1975)** OR utilizes the planned approach (updated scientific method) and an inter-disciplinary team in order to represent complex functional relatidnships as - mathematical models for purpose of providing a quantitative basis for decision making and uncovering new problems for quantitative analysis.

4.1.1 Nature

Q2. Explain the nature of operations research.

Ans :

- The term "Operations Research" refers to the application of scientific methodology of several different disciplines to problems related to the functioning or operating of some unit business, government or institutions.
- The operations research are expected by managers to analyze the management problems which involve the operations of systems, to gather essential data and to interpret those data.
- Operation Research specialist help the managers to make better decisions.
- It may provide top-level administrators with a quantitative basis for decisions that will increase the effectiveness of such organisations in carrying out their basic purpose.
- All operational level, O.R. provides scientific rates of decision making.

Q3. What are the main characteristics of operations research.

(OR)

Give the main characteristics of operations research.

Ans : **(Imp.)**

1. Distinct Direction in Decision Making

Operations Research model provides a clear and distinct direction to the managers in decision making and problem solving. A

major premise of Operations Research is that decision making irrespective of the situation involved, can be considered as a general systematic process.

2 Scientific Approach

Operations Research employs scientific reasoning to its problems. Therefore the managers can confidently implement their decisions. Even if they fail after taking a decision provided by Operations Research, they will have scientific and evidential basis to plead in their support.

3. Objective Orientation

Operations Research is oriented to locate the. best possible or optimal solution to the problem. As the approach itself is embedded with setting of the goal or objectives, it becomes easy to use this as a measure to compare the alternative courses of action.

4. Inter - Disciplinary Team Approach

Operations Research is inter disciplinary in nature and therefore needs a team approach. It is a blend of the aspects of various disciplines such as economics, physics, physiology, sociology, anatomy, engineering, technology, mathematics, statistics and management. This feature keeps Operations Research on the common berth to all sectors of people and builds an espirit-de-corps. It can also provide a solution acceptable to all the people.

5. Compatible to Digital Computer

Perhaps the use of digital computer has become an integral part of the Operations Research approach to decision making. There are several software packages developed with the help of Operations Research approach to problems with high volume and complexive in nature.

6. Consideration of All Factors

Operations Research takes into account of the goals (objective function) of the organization with all bottlenecks or hurdles (constraint set) and the feasibility (conditions of variables). This feature provides a manager to take a decision that can keep himself or his organization on a competitive edge.

Q4. Discuss the various phases in solving an OR problem.

(OR)

What are the various phases of OR problem? Explain them briefly.

Ans : **(Imp.)**

The procedure for an OR study generally involves the following major phases :

Phase I: Formulating the problem

Before proceeding to find the solution of a problem, first of all one must be able to formulate the problem in the form of an appropriate model. To do so, the following information will be required.

(i) Who has to take the decision ?

(ii) What are the objectives ?

(iii) What are the ranges of controlled variables ?

(iv) What are the uncontrolled variables that may affect the possible solutions ?

(v) What are the restrictions or constraints on the variables ?

Since wrong formulation cannot yield a right decision (solution), one must be considerably careful while execution this phase.

Phase II: Constructing a mathematical model

The second phase of the investigations is concerned with the reformulation of the problem in an appropriate form which is convenient for analysis. The most suitable form for this purpose is to construct a mathematical model representing the system under study. It requires the identification of both static and dynamic structural elements. A mathematical model should include the following three important basic factors :

(i) Decision variables and parameters,

(ii) Constraints or Restrictions,

(iii) Objective function.

Phase III: Deriving the solutions from the model.

This phase is devoted to the computation of those values of decision variables that maximize (or minimize) the objective function. Such solution is called an optimal solution which is always in the best interest of the problem under consideration. The general techniques for deriving the solution of OR model are discussed in the following sections and further details are given in the text.

Phase IV: Testing the model and its solution

After completing the model, it is once again tested as a whole for the errors if any. A model may be said to be valid if it can provide a reliable prediction of the system's performance. A good practitioner of Operations Research realises that his model be applicable for a longer time and thus he updates the model time to time by taking into account the past, present and future specifications of the problem.

Phase V : Controlling the solution.

This phase establishes controls over the solution with any degree of satisfaction. The model requires immediate modification as soon as the controlled variables (one or more) change significantly, otherwise the model goes out of control. As the conditions are constantly changing in the world, the model and the solution may not remain valid for a long time.

Phase VI : Implementing the solution

Finally, the tested results of the model are implemented to work. This phase is primarily executed with the cooperation of Operations Research experts and those who are responsible for managing and operating the systems.

4.1.2 Managerial Applications of OR

Q5. "Operations Research replace management by personality". Discuss.

(OR)

Explain applications of OR in industry.

(OR)

Explain the managerial applications of OR.

Ans : **(Dec.-20, July-19, Dec.-18)**

Some of the areas of management decision making, where the 'tools and techniques of OR are applied, can outlined as follows :

1. Finance Budgeting and Investments

(i) Cash-flow analysis, long range capital requitements, dividend policies, investment portfolios.

(ii) Credit policies, credit risks and delinquent account procedures.

(iii) Claim and complaint procedures.

2. Purchasing, Procurement and Exploration

(i) Rules for buying, supplies and stable or varying prices'.

(ii) Determination of quantities and timing of purchases.

(iii) Bidding policies.

(iv) Strategies for exploration and exploitation of raw materia! sources.

(v) Replacement policies.

3. Production Management

(i) Physical Distribution

(a) Location and size of warehouses, distribution centres and retail outlets.

(b) Distribution policy.

(ii) Facilities Planning

(a) Numbers and location of factories, warehouses, hospitals etc.

(b) Loading and unloading facilities for railroads and trucks determining the transport schedule.

(iii) Manufacturing

(a) Production scheduling and sequencing.

(b) Stabilization of production and employment training, layoffs and optimum product mix.

(iv) Maintenance and Project Scheduling

(a) Maintenance policies and preventive maintenance.

(b) Maintenance crew sizes.

(c) Project scheduling and allocation of resources.

4. Marketing

(i) Product selection, timing, competitive actions.

(ii) Number of salesman, frequency of calling on accounts per cent of time spent on prospects.

(iii) Advertising media with respect to cost and time.

5. Personnel Management

(i) Selection of suitable personnel on minimum salary.

(ii) Mixes of age and skills.

(iii) Recruitment policies and assignment of jobs.

6. Research and Development

(i) Determination of the areas of concentration of research and development.

(ii) Project selection.

(iii) Determination of time cost trade-off and control of development projects.

(iv) Reliability and alternative design.

4.1.3 Limitations of OR

Q6. What are the Limitations of OR approach ?

(OR)

Explain the limitations of OR.

Ans : **(Dec.-20, Dec.-18)**

1. Magnitude of Computation

Operations research tries to find out the optimal solution taking all the factors in to account. In the modern society these factors are numerous and expressing them in quantity and establishing, relationships among these requires huge calculations. All these calculations cannot be handled manually, but require electronic computes which bear very heavy cost. Thus, the use of OR is limited to very large organizations.

2. Absence of Quantification

Operations research provides solution only when all the elements related to a problem can be quantified. The tangible factors such as price product, etc., can be expressed in terms of quantity, but intangible factors such as human relations, etc., cannot be quantified. Thus, these intangible elements of the problem are excluded from the study, though these might be equally or more important than quantifiable elements. Now a days, attempts are being made to quantify even the intangible factors as far as possible

3. Distance between Managers and Operation Research

Operations research being specialists' job, requires mathematician or statistician who might not be aware of the business problems. Similarly, a manager fails to understand the complex working of OR.

4.2 Types of Operation Research Models

Q7. Explain different types of operation research models.

Ans :

OR model is a representation of a real life situation. OR models can be studied by classifying in many ways. These are discussed here below :

I) Classification Based on Structure

1 Physical Models

These models give a physical appearance of the real object either in reduced form or scaled up. These are further divided into two categories.

(i) Iconic Models : These are representations in either idealised form (or) a scaled version, (i.e., enlarging or

reducing in size) of real objects, e.g., Blue prints, Globe, Photographs, Drawings, Templates etc.

(ii) Analogue Models : These models represent a system by a set of properties different from that of the original system, and physically do not resemble. After attaining solution, it is re-interpreted in terms of original system, e.g., frequency curves, flow charts, organization charts etc.

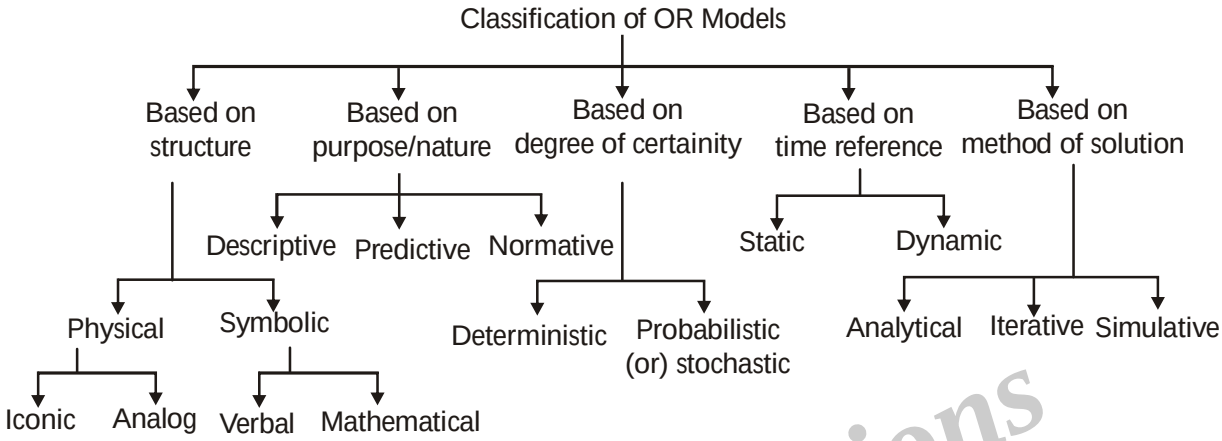


Fig.: Classification of OR Models

2. Symbolic Models

These models use symbols in the form of letters, V. mathematical operators or any other symbols to represent the properties of the system. These are often described in two types.

(i) Verbal Models : These models are used to describe a situation in written or spoken language in the form of letters, words and sentences.

(ii) Mathematical Models : These models use mathematical symbols, letters, numbers and mathematical operators to represent relationship among various variables of the system to explain its behaviour and properties.

II) Classification Based on Purpose and Nature

(i) Descriptive Models : The reports of surveys, questionnaire results, inferences of the observations etc., are used in such models to describe the situation. These also include the models such as plant layout diagram, block diagram of an algorithm etc.

(ii) Predictive Models : These models are results of the quiery such as "what will follow if this occurs or does not occur?" e.g. Preventive maintenance schedules.

(iii) Normative Model (or Optimization Models) : These models are designed to provide 'optimal' solution to the problems subject to certain limitations on the use of resources or meeting the requirements or at the conditions that normally exist, e.g. Linear Programming Problem.

III) Based on Certainty

(i) Deterministic Model : If all the parameters of decision variables, constants and their functional relationship are known (or assumed to be known) with certainty, then the model is said to be deterministic, e.g. Certain inventory models, games with saddle points.

(ii) Probabilistic (or Stochastic) Model : This is the model in which at least one parameter or decision variables is a random variable. e.g. Probabilistic inventory models, games without saddle points, queuing models.

IV. Based on Time Reference

(i) Static Model : These models present a system at a specified time, which do not account for changes over certain period of time. e.g. Replacement of machines when money value is not changing with time.

(ii) Dynamic Model : Time is considered as one of the variables and the impact of changes generated by time is accounted while selecting the optimal course of action, e.g. Machine replacement model when money value is changing with time.

V. Based on Method of Solution

(i) Analytical Model : These have a specific mathematical structure and hence can be solved by analytical Or mathematical techniques, e.g. Any optimization model, such as inventory models, waiting lines etc.

(ii) Iterative Models : In these models, the solution is obtained from the conclusion of previous step. e.g. Simplex method for LPP, dynamic programming.

(iii) Simulation Models : Though these models have a mathematical structure, they can not be solved by applying mathematical techniques. Instead, a simulation model is essentially a computer assistant experimentation on a mathematical structure of a real life problem under certain assumptions over a period of time. e.g. Monte-Carlo simulation, use of random numbers, forecasting models etc.

4.3 LINEAR PROGRAMMING

Q8. What is Linear Programming Problem? Discuss the components of LPP.

Ans : **(July-19)**

In 1947, George dantzig and his associates, while working in the U.S. department of Air Force, observed that a large of military programming and planning problems could be formulated as maximizing/minimizing a linear form of profit/cost function whose variables were restricted to values satisfying a system of linear constraints.

A linear form is meant a the matically expression of the type $a_1x_1 + a_2x_2 + ... + a_nx_n$, where $a_1, a_2, ..., a_n$ are constants and $x_1, x_2, ..., x_n$ are variables. The term 'Programming' refers to the process of determining a particular programme or plan of action. So Linear Programming (L.P.) is one of the most important optimization (maximization/ minimization) techniques developed in the field of Operations Research.

Components

1. Objective Function

This is the function which is formulated by using contributions (i.e., profits, cost) and this function is to be optimized i.e., to maximize the profit and minimize the loss respectively.

It is formulated by considering contributions and decision variables. It should be a linear equation.

2. Constraints

An objective function is always limited by some restrictions called as constraints.

(i) Demand Constraint

Demand is analogous to requirement. It has lower limit but upper limit is not mentioned.

(ii) Supply Constraint

Supply is related to availability. So it has upper limit.

(iii) Equality Constraint

Here, the availability and requirement should be exactly equal.

3. Decision Variables

The variables which are required to be determined using different techniques are said to be decision variables.

(i) Slack Variables

When a supply constraint is given i.e., '$\leq$' type of inequality. Thus, in order to change inequality to the equality a non-negative variable should be added on left side of an equation.

(ii) Surplus Variables

When a requirement constraint is given i.e., '$\geq$' type of inequality. Thus, in order to change inequality to equality, variable should be added to inequality on right hand side of an equation.

(iii) Artificial Variables

The variable which should be added in case of minimization Linear Programming Problem (LPP) along with surplus variable is called an artificial variable.

Q9. What are the advantages and limiations of linear programming ?

Ans : **(July-19)**

Advantages

The advantages of linear programming techniques may be out-lined as follows :

1. Linear programming technique helps us in making the optimum utilization of productive resources. It also indicates how a decision maker can employ his productive factors most effectively by choosing and allocating these resources.
2. The quality of decisions may also be improved by linear programming techniques. The user of this technique becomes more objective and less subjective.
3. Linear programming technique provides practically applicable solutions since mere might be other constraints operating outside the problem which must also be taken into consideration just because, so many units must be produced does not mean that all those can be sold. So the necessary modification of its mathematical solution is required for the sake of convenience to the decision maker.
4. In production processes, high lighting of bottlenecks is the most significant advantage of this technique.

   For example, when bottlenecks occur, some machines cannot meet the demand while others remain idle for some time

Limiations

Inspite of wide area of applications, some limitations are associated with linear programming techniques. These are stated below :

1. In some problems objective functions and constraints are not linear. Generally, in real life situations concerning business and industrial problems constraints are not linearly treated to variables.
2. There is no guarantee of getting integer valued solutions, for example, in finding out how many men and machines would be required to perform a particular job, rounding off the solution to the nearest integer will not give an optimal solution. Integer programming deals with such problems.
3. Linear programming model does not take into consideration the effect of time and uncertainty. Thus the model should be defined in such a way that any change due to internal as well as external factors can be incorporated.
4. Sometimes large-scale problems cannot be solved with linear programming techniques even when the computer facility is available. Such difficulty may be removed by decomposing the main problem into several small problems and then solving them separately.
5. Parameters appearing in the model are assumed to be constant. But, in real life situations they are neither constant nor deterministic.
6. Linear programming deals with only single objective, whereas in real life situations problems come across with multiobjectives. Goal programming and multi-objective programming deal with such problems.

4.3.1 Mathematical Model of LPP

Q10. Discuss Mathematical Model of LPP.

Ans : **(July-19)**

In order to find the values of n decision variables $x_1, x_2, ..., x_n$ to maximize or minimize the objective function

$$z = c_1x_1 + c_2x_2 + c_3x_3 + ... + c_nx_n$$

and also satisfy m-constraints :

$$\left.\begin{array}{l} a_{11}x_1 + a_{12}x_2 + ... + a_{1j}x_j + ... + a_{1n}x_n (\leq = \text{or} \geq) b_1 \\ a_{21}x_1 + a_{22}x_2 + ... + a_{2j}x_j + ... + a_{2n}x_n (\leq = \text{or} \geq) b_2 \\ \quad \vdots \qquad \vdots \qquad \vdots \qquad \vdots \qquad \vdots \\ a_{i1}x_1 + a_{i2}x_2 + ... + a_{ij}x_j + ... + a_{in}x_n (\leq = \text{or} \geq) b_i \\ \quad \vdots \qquad \vdots \qquad \vdots \qquad \vdots \qquad \vdots \\ a_{m1}x_1 + a_{m2}x_2 + ... + a_{mj}x_j + ... + a_{mn}x_n (\leq = \text{or} \geq) b_m \end{array}\right\}$$

where constraints may be in the form of any inequality ($\leq$ or $\geq$) or even in the form of an equation (=) and finally satisfy the non-negativity restrictions

$x_1 \geq 0,\ x_2 \geq 0,\ ..., x_j \geq 0,\ ..., x_n \geq 0.$

4.3.2 Formulation of LPP

Q11. Explain the formulation of LPP.

Ans : **(July-19)**

Step 1: Selection of Variables

In the given data, firstly the variables are to be identified. These are also called decision variables or design variables.

Step 2: Setting Objective Function

This is to set the goal in the problem. There are only two types of objective functions in Operations Research.

There are : Maximization (of profits) and Minimization (of costs).

A maximization type of objective function is set if the data reveals the profits in the problem. The production, sales, revenue, output etc, are to be maximized.

Step 3: Identifying the Constraint Set

A constraint set is a set of the hurdles or limitations in achieving the objective.

The different types of constraints we come across in linear programming problem are given below :

(i) Availability Constraint : This is related by an inequality, less than or equal to (<) and is used when the availability of resource is limited or when maximum limit is imposed.

Example, Suppose you are cooking some curry dish and you have to put some salt in it, say 10 gm. You will be constrained to put less than or equal to 10 gm-only, but excess is not allowed.

(ii) Requirement Constraint : This constraint is used to show a relation 'greater than or equal to' type of inequality. This constraint is used when certain minimum limit is imposed. Here, more than certain limit is permitted but lesser quantity is not allowed.

Example, You are to buy a ready made trouser or skirt. You will be constrained to choose greater than (or) equal to the required length.

(iii) Exact Constraint : This is the constraint which can deviate to neither side. This is represented in the equation (=) form.

Example, You have to order the lens power for your spectacles. Here you will not permit lesser (or) greater than your specified power.

Step 4: Writing Conditions of Variables

Here the conditions of the decision variables will be predetermined. The conditions often found in LPP are in two kinds. These are non-negative and unrestricted. A non-negative conditions is represented by 'greater than equal to zero' ($\geq$ 0).

Q12. Explain how a two person zero sum game can be solved by linear programming.

Ans : **(Dec.-19)**

Games which are of size m × n, where m > 2, n > 2 even after reducing the size using dominance principle, can be solved using linear programming approach. Every game matrix can be formulated from the point of view of the player in the row or from the point of view of the player in the column. The two person zero sum game can be solved by Linear Programming method. Following example illustration will help to understand the solving process,

Example of Two Person Zero-Sum Game by Linear Programming

		B's strategy		
		B_1	B_2	B_3
	B_2	a_{11}	a_{12}	a_{13}
A's strategy	B_2	a_{21}	a_{22}	a_{23}
	B_3	a_{31}	a_{32}	a_{33}

From A's Point of View

The player A is interested in maximizing the minimum gain.

Let this value of game be called 'U'.

Let x_t, x_2 and x_3 be the probabilities with which A plays the strategies A_1, A_2 and A_3

Let E_1 E_2 and E_2 be the expected payoffs of A when B decides to play B_1, B_2 and B_2 respectively.

$$E_1 = a_{11}x_1 + a_{2l}x_2 + a_{31}x_3$$

$$E_2 = a_{l2}x_1 + a_{22}x_2 + a_{32}x_3$$

$$E_3 = a_{13}x_1 + a_{23}x_2 + a_{33}x_3$$

Maximize $U = x_t + x_2 + x_3$

Subject to, $a_{11}x_1 + a_{21}x_2 + a_{31}x_3 \geq U$ (i.e., E_1)

$a_{12}x_1 + a_{23}x_2 + a_{32}x_3 \geq U$ (i.e., E_2)

$a_{13}x_1 + a_{23}x_2 + a_{32}x_3 \geq U$ (i.e., E_3)

Divide all the constraint by U and set $X_i = \frac{x_i}{U}$

Minimize $\frac{1}{U} = X_1 + X_2 + X_2$

Subject to, $a_{11}X_1 + a_{21}X_2 + a_{31}X_3 \geq 1$

$a_{12}X_1 + a_{22}X_2 + a_{32}X_3 \geq 1$

$a_{13}X_1 + a_{22}X_2 + a_{32}X_3 \geq 1$

and $X_1, X_2, X_3 \geq 0$

Similarly, develop the LPP from B's point of view.

Maximize $\frac{1}{V} = Y_1 + Y_2 + Y_3$

Subject to, $3Y_1, -4Y_2 + 2Y_3 \leq 1$

$Y_1 - 3Y_2 + 7Y_3 \leq 1$

$Y_1 - 4Y_2 + 2Y_3 \leq 1$

and $Y_1, Y_2, Y_3 \geq 0$

This is the dual LPP fromd's point of view. Hence, solving any one LPP, we can get the solution can be obtained using simplex method.

PROBLEMS ON FORMULATION OF LPP

1. Sainath and Co manufactures two brands of products namely Shivnath and Harinath. Both these models have to undergo the operations on three machines lathe, milling and grinding. Each unit of Shivnath gives a profit of Rs. 45 and requires 2 hours on lathe, 3 hours on milling and 1 hour on grinding. Each unit of Harinath can give a profit of Rs. 70 and requires 3, 5, and 4 hours on lathe, milling and grinding respectively. Due to prior commitment, the use of lathe hours are restricted to a maximum of 70 hours in a week. The operators to operate milling machines are hired for 110 hours / week. Due to scarce availability of skilled man power for grinding machine, the grinding hours are limited to 100 hours/week. Formulate the data into on LPP.

Sol :

Step 1: Selection of Variables

In the above problem, we can observe that the decision is to be taken on how many products of each brand is to be manufactured. Hence the quantities of products to be produced per week are the decision variables.

Therefore we assume that the number of units of product Shivnath brand produced per week = x_1

The number of units of product of Harinath brand produced per week = x_2

Step 2 : Setting Objective

In the given problem the profits on the brands are given.

Therefore objective function is to maximise the profits.

Now, the profit on each unit of Shivnath brand = Rs. 45.

Number of units of Shivnath to be manufactured = x_1

$\therefore$ The profit on xj units of Shivnath brand = $45 x_1$

Similarly, the profit on each unit of Harinath brand = Rs. 70

Number of units of Harinath brand to be manufactured $= x_2$

$\therefore$ The profit on x_2 units of Harinath brand $= 70x_2$

The total profit on both brands $= 45x_i + 70x_2$

This total profit (say z) is to be maximised.

Hence, the objective function is to

$$\boxed{\text{Maximise } z = 45x_i + 70x_2}$$

Step 3 : Identification of Constraint Set

In the above problem, the constraints are the availability of machine hours.

(i) Constraint on Lathe Machine : Each unit of Shivnath brand requires 2 hours/ week

So x_1 units of Shivnath brand requires $2x_i$ hours / week.

Each unit of Harinath brand requires 3 hours / week

and So x_2 units of Harinath brand require $3x_2$ hours / week.

Total lathe hours utilised for both the brands is $2x_x + 3x_2$

and this cannot exceed 70 hours/ week.

$\therefore$ $\boxed{2x_1 + 3x_2 \le 70}$

(Constraint on availability of lathe hours due to prior commitment)

2. Constraint on Milling Machine: Milling hours requiredfor each unit of Shivnath brand = 3 hours/week.

$\therefore$ For x_1 units = $3x_1$ hours/week

Milling hours required for each unit of Harinath brand = 5 hours/week.

$\therefore$ For x_2 units = $5x_2$

Total milling hours = $3xj + 5x_2$

This can not be more than 110

$\therefore$ $\boxed{3x_1 + 5x_2 \le 110}$

(Constraint on availability of milling machine hours due to hiring)

3. Constraint on Grinding Machine : One unit of Shivnath needs one hour/week and x_1 units need x_1 hours/week One unit of Harinath needs 4 hours/week and x_2 units need $4x_2$ hours/week. Total grinding hours = $x_1 + 4x_2$ and this cannot be greater than 100 hours.

$\therefore$ $\boxed{x_1 + 4x_2 \le 100}$

(Constraint on availability of grinding hours due to scarcity of skilled labour)

Step 4 : Writing Conditions of Variables

Both x i and x_2 are the number of products to be produced. There can not exist any negative production. Therefore x_i and x_2 can not assume any negative values (i.e., non negative)

Mathematically

$\boxed{x_1 \geq 0 \text{ and } x_2 \geq 0}$

Step 5 : Summary :

Maximise $Z = 45x_1 + 70x_2$

Subject to $2x_1 + 3x_2 \leq 70$

$3x_1 + 5x_2 \leq 110$

$x_1 + 4x_2 \leq 100$

$x_1 \geq 0$ and $x_2 \geq 0$

2. Formulate thefollowing problem as an LP Problem:

Afirm engaged in producing 2 models X_1, X_2 performs 3 operations Painting. Assembly and Testing. The relevant data are asfollows :

Model	Units Sales Price	Hours Required for each unit		
		Assembly	Paining	Testing
Model X_1	Rs. 50	1.0	0.2	0.0
Model X_2	Rs. 80	1.5	0.2	0.1

Total number ofhours available are:

For Assembly 600

For Painting 100

For Testing 30

Determine weekly production schedule to maximise revenue.

Sol :

Step 1: Variables

Let the weekly produced units of model $X_i = x_t$

i.e., Let the no. of units produced per week in Model Xj = x_t and let the no. of units produced per week in model $X_2 = x_2$

Step 2: Objective Functior

Unit sales price for model Xj = Rs. 50/-

For x_1 units, weekly sales revenue = $50 x_1$

Similarly, unit sales price for model X_2 = Rs. 80/-

For x_2 units, weekly sales revenue = $80 x_2$

Total sales revenue per week = $50 x_1 + 80 x_2$

Hence the objective funcdon is to -

$\boxed{\text{Maximise } Z = 50 x_1 + 80 x_2}$

Step 3: Constraint Set

For assembly,

one unit of model X_1 requires 1.0 hrs.

$\therefore$ x_1 units require 1.0 x_1 hrs.

one unt of model X_2 requires 1.5 hrs.

x_2 units of model X_2 requires 1.5 x_2 hrs.

Total assembly hours per week = $l.0x_1 + 1.5\ x_2$.

This cannot exceed 600 hrs since only 600 hrs are available for assembly.

$\therefore$ $\boxed{1.0x_1 + 1.5x_2 \leq 600}$

(Constraint on availability of assembly hours)

Similarly,

For painting

x_1 units require 0.2 x_1 hrs

and x_2 units require 0.2 x_2 hrs

$\therefore$ $\boxed{0.2x_1 + 0.2x_2 \leq 100}$

(Constraint on availability of painting hours)

For Testing

$0.0\ x_1 + 0.1\ x_2 < 30$

or

$\boxed{0.1x_2 \leq 30}$

(Availability constraint on testing hours)

Step 4: Conditions of Variables

As the problem is to determine weekly production schedule and we cannot have a negative production.

Therefore,

$\boxed{x_1 \geq 0 \text{ and } x_2 \geq 0}$

Step 5: Summary of Formulation

maximize $Z = 50\ x_1 + 80\ x_2$

subject to $1.0\ x_1 + 1.5\ x_2 \leq 600$

$0.2\ x_1 + 0.2\ x_2 \leq 100$

$0.1\ x_2 \leq 30$

$x_1, x_2 \geq 0$

3. A firm manufactures two products in three departments. Product A contributes Rs. 5/- unit and requires 5 hrs. in dept. M, 5 hrs. in dept Nand one hour in dept P. Product B contributes Rs. 10/- unit and requires 8 hrs. in dept M, 3 hrs in dept N and 8 hrs in dept P. Capacities for departments M, N, P are 48 hours per week.

Sol :

The problem is summarised below.

Unit contribution 5 10

Step 1: Variables

Let quantity produced of product A = X_1

Let quantity produced of product B = X_2

Step 2: Objective Function

Profit contribution of each unit of A = Rs. 5

Profit contribution of X_1 units of A = 5 X_1

Profit contribuuon of each unit of B = Rs. 10

Profit contribution of X_2 units of B = 10 X_2

Total profit = 5 X_1 + 10 X_2

Therefore objective function is to $\boxed{\text{maximise } Z = 5X_1 + 10X_2}$

Step 3: Constraint Set

In Department M

Time required by each unit of product A = 5 hrs

Time required by X_1 units of product A = 5 X_1

Time required by each unit of product B = 8

Time required by X_2 units of product B = 8 X_2

Total hours available in dept. M = 48 hrs per week

$\therefore$ $\boxed{5X_1 + 8X_2 \leq 48}$

(Constraint on capacity in dept. M)

Similarly in department N,

$\boxed{5X_1 + 3X_2 \leq 48}$

(Constraint on capacity in dept. N.)

and in department P,

$$\boxed{X_1 + 8X_2 \leq 48}$$

(Constraint on capacity in department P)

Step 4: Conditions

X_1 and $X_2 \geq 0$

Step 5: Summary

Max $Z = 5X_1 + 10X_2$

Subject to $5X_1 + 8X_2 \leq 48$

$5X_1 + 3X_2 \leq 48$

$X_1 + 8X_2 \leq 48$

$X_1, X_2 \geq 0$

---

4. Food X contains 6 units of Vitamins A per gram and 7 units of Vitamin B per gram and costs 12 paise per gram. Food Y contains 8 units of Vitamin A per gram and 12 units of Vitamin B and costs 20 paise per gram. The daily minimum requirements of Vitamin A and Vitamin B are 100 units and 120 units respectively. Find the minimum cost of product mix.

Sol :

Step 1: Selection of Variables

Let the No. of grams produced in type X = x_1

Let the No. of grams produced in type Y = x_2

Step 2: Objective Function

Cost of each gram of type X = 12 paise

Cost ofxj gms of type X = $12x_1$ ps.

Cost of each gm of type 7 = 20 ps.

Cost of x_2 gms of type 7 = $20x_2$ ps.

Total cost Z = $12x_1 + 20x_2$

$\therefore$ Objective function is to $\boxed{\text{minimize } Z = 12x_1 + 20x_2}$

Step 3: Constraint Set:

For Vitamin A

Availability of vitamin A in each gm of food X = 6 units

Availability of vit-A in gms of food X = $6 x_1$

Availability of vit-A in each gms of food Y = 8 units

Availability of vit-A in x_2 gms of food Y = $8 x_2$

Total vitamin A = 6xj + $8x_2$

Daily minimum vitamin A required = 100 units

$$\boxed{6x_1 + 8x_2 \geq 100}$$

(Requirement constraint on vitamin A)

For Vitamin B

Availability of vitamin B in each gm of food X = 7 units

Availability of vit-B in xj gms of food X = $7 x_1$

Availability of vit-B in each gms of food Y = 12

units Availability of vit-B in x_2 gms of food Y = $12 x_2$

Total vitamin B = $7 x_1 + 12 x_2$

Daily minimum requirement of vitamin B = 120 units

Hence $\boxed{7x_1 + 12x_2 \geq 120}$

(Constraint on requirement of vitamin — B).

Step 4: Conditions of Variables

x_1 and x_2 cannot be negative

$\therefore$ $\boxed{x_1 \geq 0}$ & $\boxed{x_2 \geq 0}$

Step 5: Summary

minimize $= 12 x_1 + 20 x_2$

subject to $6x_1 + 8x_2 \geq 100$

$7x_1 + 12x_2 \geq 120$

$x_1, x_2 \geq 0$

5. M/s. ABCL company manufactures two types of cassettes, a video and audio. Each video cassette takes twice as long to produce one audio cassette, and the company would have time to make a maximum of 2000per day if it is produced only audio cassettes. The supply of plastic is sufficient to produce 1500per day to both audio and video cassettes combined. The video cassette requires a special testing and processing of which there are only 6000 hrs. per day available. If the company makes a profit of Rs.3/- and Rs. 5/- per audio and video cassette respectively, how many of each should be produced per day in order to maximize the profit ?

Sol :

Let No of audio cassettes to be produced per day = x_1

No. of video casettes to be produced per day = x_2

Objective Function

Profit per one audio casette = Rs. 3

Profit on audio casettes = 3x

Profit on each video casette = 5

Profit on xj video casettes = $5x_2$

Total profit = $3x_1 + 5x_2$

It is to be maximized

$\therefore$ Objective function is to Maximize

$$Z = 3x_1 + 5x_2$$

Constraint Set :

(i) Time Constraint

As time of production of video is twice to that of audio cassettes, if x_1 audio are produced $\frac{x_2}{2}$ videos can be produced. Thus in terms of audio casette times, we get

$$x_1 + \frac{x_2}{2} \leq 2000 \qquad \text{(constraint on production time)}$$

$$\Rightarrow \quad 2x_1 + x_2 \leq 4000$$

(ii) Plastic Constraint

$$x_1 + x_2 \leq 1500$$

(iii) Testing & Processing Time Constraint

$$x_2 \leq 6000$$

Conditions Both $x_1 \geq 0$ and $x_2 \geq 0$

Summary Maximize $Z = 3x_1 + 5x_2$

Subject to $2x_1 + x_2 \leq 4000$

$x_1 + x_2 \leq 1500$

$x_2 \leq 6000$

$x_1, x_2 \geq 0$

4.3.3 Assumptions underlying LPP

Q13. Explain the major assumptions of LPP.

Ans : **(Imp.)**

1. **Proportionality :** A primary requirement of linear programming problem is that the objective function and every constraint function must be *linear*. Roughly speaking, it simply means that if 1 kg of a product costs Rs. 2, then 10 kg will cost Rs. 20. If a steel mill can produce 200 tons in 1 hour, it can produce 1000 tons in 5 hours.

   Intuitively, linearity implies that the product of variables such as $x_1 x_2$, powers of variables such as x_3^2, and combination of variables such as $a_1x_1 + a_2 \log x_2$, are not allowed.

2. **Additivity :** Additivity means if it takes t_1 hours on machine G to make product a and t_2 hours to make product B, then the time on machine G devoted to produce A and B both is $t_1 + t_2$, provided the time required to change the machine from product A to B is negligible.

   Then additivity may not hold, in general. If we mix several liquids of different chemical composition, then the total volume of the mixture may not be the sum of the volume of individual liquids.

3. **Multiplicativity :** It requires :
   (a) It takes one hour to make a single item on a given machine, it will take 10 hours to make 10 such items.
   (b) The total profit from selling a given number of units is the unit profit times the number of units sold.

4. **Divisibility :** It means that the fractional levels of variables must be permissible besides integral values.

5. **Deterministic :** All the parameters in the linear programming models are assumed to be known exactly. While in actual practice, production may depend upon change also.

6. **Sensitivity :** Further, the problem can be extended by sensitivity analysis to check the post optimal situations.

7. **Decision Making by Conditions :** The conditions on the answers stated at the begining of the problem will aid the decision making. The assumptyions such as non negativity (or) unrestricted variables can influence the answers.

4.4 Solution by Graphical Method

Q14. What do you mean by Graphical Method of LPP? State the characteristics of Graphical Method.

(OR)

Explain the LPP by graphical method.

(OR)

Explain about the solution by graphical method.

Ans : **(Dec.-20, Dec.-18)**

Graphical method is a simple method to understand and also to use. This is effectively used in LPP's which involves only 2 variables. It gives the graphical representation of the solutions.

All types of solutions are highlighted in this method very clearly. The only drawback is that more the number of constraints, more will be the straight lines which makes the graph difficult to understand.

Characteristics

The following are the characteristics of graphical method of LPP :

1. Method is very simple and easy to understand.
2. Very sensitive analysis and can be illustrated very easily by drawing graphs.
3. Very easy to obtain optimal solution.
4. It consumes very less time.

Q15. What are the merits and demerits of graphical method ?

Ans :

Merits

1. Graphical solutions are easier to understand and reproduce.
2. It is a pictorial view is always a better representattion.
3. A graphical solutions have gained prominence in Operations Research.

Demerits

However, graphical solutions have certain limitations such as :

1. Limited to the problems of two decision variables only.
2. Accuracy can not be obtained.
3. Some times it is difficult to represent certain expressions, particualy in the case of non linear expressions.

Q16. Explain the procedure for generating solution to an LPP graphical method.

Ans :

Simple linear programming problems of two decision variables can be easily solved by graphical method. The outlines of graphical procedure are as follows :

The steps involved in graphical method are as follows.

Step 1: Consider each inequality constraint as equation.

Step 2 : Plot each equation on the graph as each will geometrically represent a straight line.

Step 3 : Mark the region. If the inequality constraint corresponding to that line is $\leq$ then the region below the line lying in the first quadrant (due to non-negativity of variables) is shaded. For the inequality constraint $\geq$ sign, the region above the line in the first quadrant is shaded. The points lying in common region will satisfy all the constraints simultaneously. The common region thus obtained is called the feasible region.

Step 4 : Assign an arbitrary value say zero for the objective function.

Step 5 : Draw the straight line to represent the objective function with the arbitrary value (i.e. a straight line through the origin).

Step 6 : Stretch the objective function line till the extreme points of the region. In the maximization case this line will stop farthest from the origin and passing through at least one corner of the feasible region. In the minimization case, this line will stop nearest to the origin and passing through at least one corner of the feasible region.

Step 7 : Find the co-ordinates of the extreme points selected in step 6 and find the maximum (or) minimum value of Z.

PROBLEMS

6. Solve the following LPP by graphical method.

Minimize $Z = 20X_1 + 10X_2$

Subject ot $X_1 + 2X_2 \leq 40$

$3X_1 + X_2 \geq 30$

$4X_1 + 3X_2 \geq 60$

$X_1, X_2 \geq 0.$

Sol :

Replace all the inequalities of the constraints by equation

$X_1 + 2X_2 = 40$ If $X_1 = 0 \Rightarrow X_2 = 20$

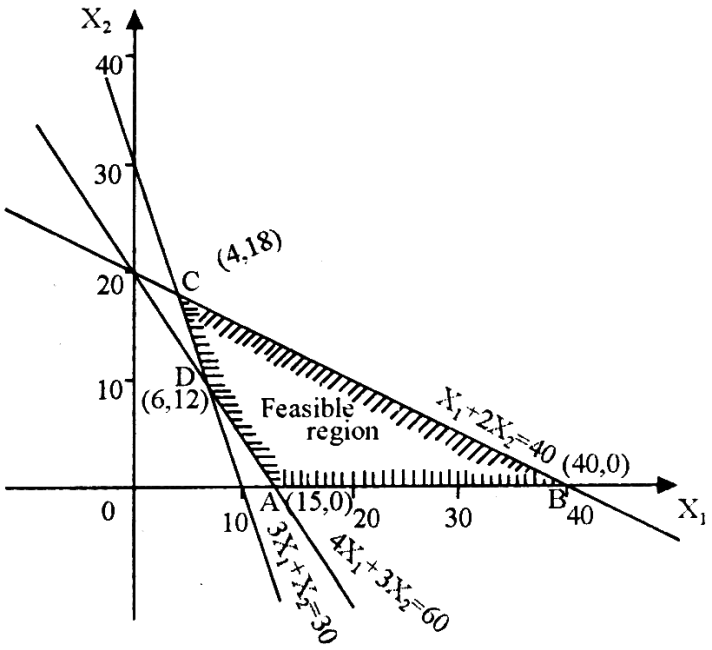
If $X_2 = 0 \Rightarrow X_1 = 40$

$\therefore$ $X_1 + 2X_2 = 40$ passes through (0, 20) (40, 0)

$3X_1 + X_2 = 30$ passes through (0, 30) (10, 0)

$4X_1 + 3X_2 = 60$ passes through (0, 20) (15, 0)

Plot each equation on the graph.



The feasible region is ABCD

C and D are point of intersection of lines

$X_1 + 2X_2 = 40$, $3X_1 + X_2 = 30$ and

$4X_1 + 3X_2 = 60$, $X_1 + X_2 = 30$

on solving web get C = (4, 18)

D = (6, 12)

Corner points	value of $Z = 20x_1 + 10X_2$
A(15, 0)	300
B(40, 0)	800
C(4,18)	200
D(6, 12)	240 (Minimum value)

∴ The minimum value of Z occurs at D(6, 12). Hence, the optimal solution is $X_1 = 6$, $X_2 = 12$

7. Find the maximum value of $Z = 5X_1 + 7X_2$

Subject to the constraints

$$X_1 + X_2 \leq 4$$

$$3X_1 + 8X_2 \leq 24$$

$$10X_1 + 7X_2 \leq 35$$

$$X_1, X_2 > 0$$

Sol :

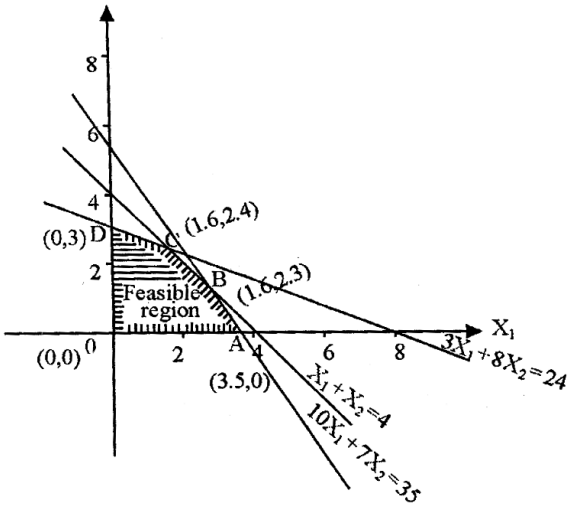
Replace all the inequalities of the constraints by forming by forming equations

$X_1 + X_2 = 4$ passes through (0,4) (4,0)

$3X_1 + 8X_2 = 24$ passes through (0, 3) (8,0)

$10X_1 + 7X_2 = 35$ passes through (0,5) (3.5,0)

Plot these lines in the graph and mark the region below the line as the inequality of the constraints is ≤ and is also lying in the firs, quadrant.



The feasible region is OABCD.

B and C are point of instruction of lines

$X_1 + X_2 = 4$, $10X_1 + 7X_2 = 35$ and

$3X_1 + 8X_2 = 24$, $X_1 + X_2 = 4$.

On solving we get,

B = (1.6, 2.3)

C = (1.6, 2.4)

Corner points	Value of $Z = 5X_1 + 7X_2$
O (0, 0)	0
A (3.5, 0)	17.5
B (1.6, 2.3)	25.1
C (1.6, 2.4)	24.8 (Maximum value)
D (0, 3)	21

$\therefore$ The maximum value of Z occurs at C (1.6, 2.4) and the optimal solu-tion is $X_1 = 1.6$, $X_2 = 2.4$.

8. Solve graphically the following LPP

Maximize (z) = $5x_1 + 3x_2$

Subject to Constraints :

$3x_1 + 5x_2 \leq 15$; $5x_1 + 2x_2 \leq 10$; $x_1, x_2 \geq 0$

Sol :

In order to plot the constraints on the graph we convert inequalities into equations

i.e., $3x_1 + 5x_2 = 15 \Rightarrow$ (1)

$5x_1 + 2x_2 = 10 \Rightarrow$ (2)

To plot $3x_1 + 5x_2 = 15$

put $x_1 = 0$, $x_2 = 3 \Rightarrow$ (0, 3)

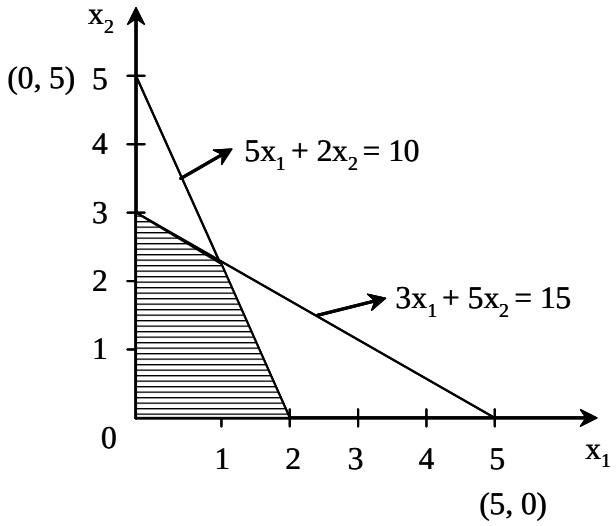
$x_2 = 0$, $x_1 = 5 \Rightarrow$ (5, 0)

To plot $5x_1 + 2x_2 = 10$

put $x_1 = 0$, $x_2 = 5 \Rightarrow$ (0, 5)

$x_2 = 0$, $x_1 = 2 \Rightarrow$ (2, 0)

Plotting these equations on the graph, we get



The area OABC is the figure satisfied by the constraints is shown by shaded area and is called the feasible solution region.

Hence Max z = 12.5, the solution to the given problem is

$\therefore \quad x_1 = 1, \; x_2 = 2.5$

9. Solve graphically the following LPP

Maximize $Z = 3x_1 + 2z_2$

S.T.C. :

$$-2x_1 + x_2 \leq 1$$

$$x_1 \leq 2$$

$$x_1, x_2 \geq 0$$

Sol :

Convert inequalities into equations

$-2x_1 + x_2 = 1$

$x_2 = 2$

$x_1 + x_2 = 3$

To plot $-2x_1 + x_2 = 1$,

put $x_1 = 0, \; x_2 = 1 \Rightarrow (0, 1)$

$x_2 = 0, \quad x_1 = -\frac{1}{2} \Rightarrow \left(-\frac{1}{2}, 0\right)$

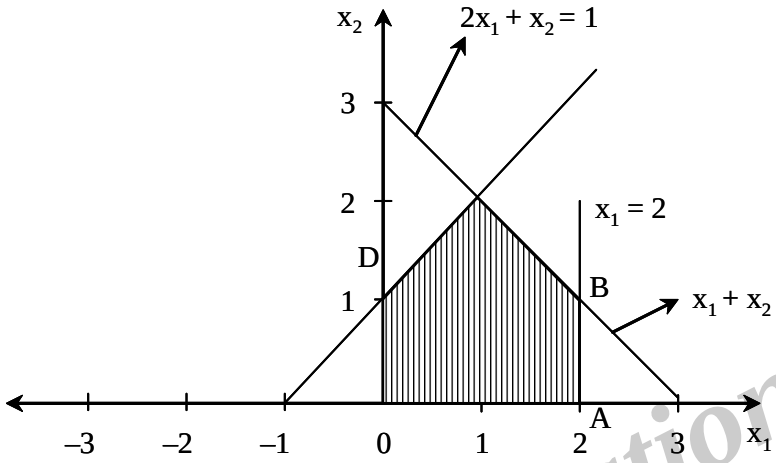
$x_1 = 2 \Rightarrow (2, 0)$

To plot $x_1 + x_2 = 3$,

put $x_1 = 0,\ x_2 = 3 \Rightarrow (0, 3)$

$x_2 = 0,\ x_1 = 3 \Rightarrow (3, 0)$

Plotting these equations on the graph, we get



Corner Points	Coordinates	Max Z = $3x_1 + 2x_2$	Value
O	(0, 0)	3(0) + 2(0)	0
A	(2, 0)	3(2) + 2(0)	6
B	(2, 1)	3(2) + 2(1)	8
C	(1, 2.3)	3(1) + 2(2.3)	7.6
D	(0, 1)	3(0) + 2(1)	2

Hence Max Z = 8, $x_1 = 2$, $x_2 = 1$.

---

10. Solve the following LP problem using graphical method .

Maximize : $Z = 6x_1 + 8x_2$

Subject to :

$$5x_1 + 10x_2 \leq 60$$

$$4x_1 + 4x_2 \leq 40$$

$$x_1, x_2 \geq 0.$$

Sol :

In graphical method, the introduction of the non-negative constraints ($x_1 \geq 0$ and $x_2 \geq 0$) will eliminate the second, third and fourth quadrants of the x_1, x_2 plane as shown in the figure.

Now, we compute the coordinates on the x_1, x_2 plane. From the first constraint.

$$5x_1 + 10x_2 = 60$$

Let $x_1 = 0$ then $x_2 = 6$ similarly if $x_2 = 0$ then $x_1 = 12$. Now plot the points (0, 6) and (12, 0) on a graph as shown in figure.

$$4x_1 + 4x_2 = 40$$

Now in 2nd constraint, let $x_1 = 0$, $x_2 = 0$, similarly if $x_2 = 0$ then $x_1 = 0$ then $x_1 = 10$. Now plot the points (0, 10) and (10, 0) on a graph as shown in the figure.

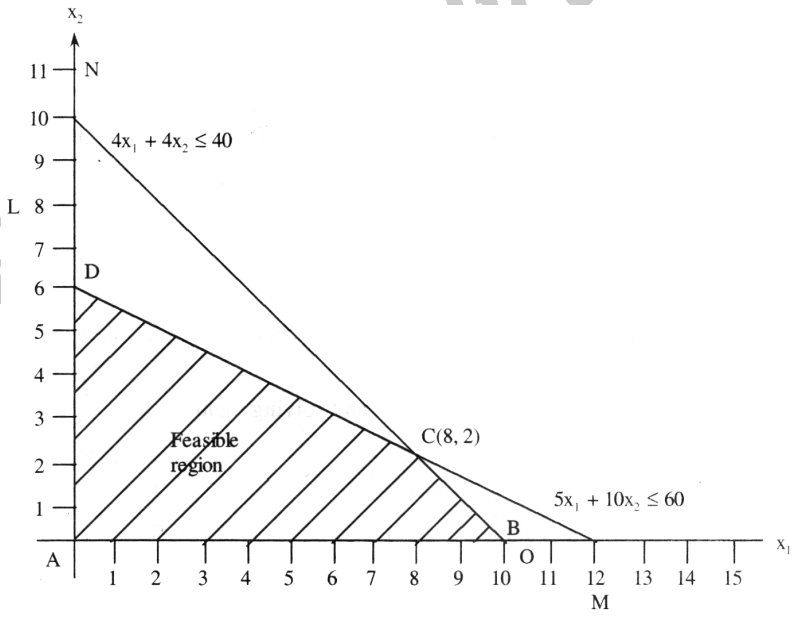
From the graph ABCD is found to be a feasible region. Points lying at the corner of the polygon must be substituted to obtain the value of an objective function as follows.

$Z(A) = 6 \times 0 + 8 \times 0 = 0$

$Z(B) = 6 \times 10 + 8 \times 10 = 60$

$Z(C) = 6 \times 8 + 8 \times 2 = 48 + 16 = 64$

$Z(D) = 6 \times 0 + 8 \times 6 = 48$



Graph : Feasible Region

Since, the type of the objective function here is maximization, the solution corresponding to the maximum Z value is to be selected as the optimum solution. The Z value is maximum for the corner point C. Hence, the corresponding solution is presented below.

$x_1^* = 8$, $x_2^* = 2$, max Z(optimum) = 64.

11. Solve the following LPP graphically

Min Z = $4x_1 + 2x_2$

S.T.C. :

$x_1 + 2x_2 \geq 2$

$3x_1 + x_2 \geq 3$

$4x_1 + 3x_2 \geq 6$

$x_1, x_2 \geq 0$

Sol :

Convert inequations into equations considering equations (1), (2) and (3)

$x_1 + 2x_2 = 2 \Rightarrow$ (1)

$3x_1 + x_2 = 3 \Rightarrow$ (2)

$4x_1 + 3x_2 = 6 \Rightarrow$ (3)

To plot $x_1 + 2x_2 = 2$

put $x_1 = 0,\ x_2 = 1 \Rightarrow (0,1)$

$x_2 = 0,\ x_1 = 2 \Rightarrow (2, 0)$

To plot $3x_1 + x_2 = 3$

put $x_1 = 0,\ x_2 = 3 \Rightarrow (0,3)$

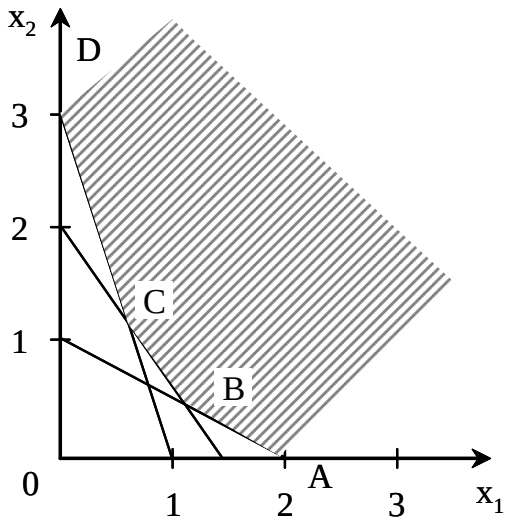
$x_2 = 0,\ x_1 = 1 \Rightarrow (1, 0)$

To plot $4x_1 + 3x_2 = 6$

put $x_1 = 0,\ x_2 = 2 \Rightarrow (0,2)$

$x_2 = 0,\ x_1 = 1.5 \Rightarrow (1.5, 0)$

Plotting these equations in the graphs, we get



Corner Points	Coordinites	Max Z = $4x_1 + 2x_2$	Value
A	(2, 0)	4(2) + 2(0)	8
B	(1.2, 0.4)	4(1.2) + 2(0.4)	5.6
C	(0.6, 1.2)	4(0.6) + 2(1.2)	4.8
D	(3, 0)	4(3) + 2(0)	6

The minimum value of z is 4.8 which occurs at C = (0.6, 1.2).

Hence, the solution to the above problem is $x_1 = 0.6$; $x_2 = 1.2$, min z = 4.8

12. An auto company has three plants A, B and C and two major distribution centers in X and Y. The capacities of the three plants during the next quarter are 1000, 2300 and 1400 cars. The transportation costs (which depend on the mileage, transport company etc) between the plants and the distribution centers is as follows :

Plant Name	Distr. Center X	Distr. Center Y
Plant A	**80**	**215**
Plant B	**100**	**108**
Plant C	**102**	**68**

Which plant should supply how many cars to which outlet so that the total cost is minimum?

Sol : **(Dec.-20)**

The problem can be formulated as a LP model:

Let x_{ij} be the number of cars to be shipped from source i to destination j. Then our objective is to minimize the total cost which is $80x_{11} + 215x_{12} + 100x_{21} + 108x_{22} + 102x_{31} + 680x_{32}$. The constraints are the ones imposed by the number of cars to be transported from each plant and the number each center can absorb.

The whole model is:

Minimize $z = 80x_{11} + 215x_{12} + 100x_{21} + 108x_{22} + 102x_{31} + 68x_{32}$

subject to,

$x_{11} + x_{12} = 1000$

$x_{21} + x_{22} = 1500$

$x_{31} + x_{32} = 1200$

$x_{11} + x_{21} + x_{31} = 2300$

$x_{12} + x_{22} + x_{32} = 1400$

Q17. Discuss about special cases in finding solution to LPP by graphical method.

Ans :

All LP problems does not have unique optimal solutions, so these problems are required as special cases. Some of the special cases in graphical method of LPP are unbounded solution, infeasible solution and multiple optimal solution.

1. Unbounded Solution

A solution to LPP that has no limits on the constraints is called an unbounded solution i.e., the common feasible region, identified in graphical method is not bounded in any respect and the primary variable can take any value in the unbounded region.

In such situation, there may or may not be optimal solution to the LPP. If the value of the objective function goes on changing in the unbounded region, then there will be no optimal solution. If the value of the objective function in the region is less than the value of the vertex, the optimal solution will be existing.

2. Infeasible Solution

A solution that does not satisfy the constraints of an LP problem is called infeasible solution i.e., it is a condition that arises when there is no solution to a LPP that satisfies all the constraints. Graphically, it can be concluded as when there is no feasible solution region existing. This generally happens when the LPP was formulated with conflicting constraints.

3. Multiple Optimal Solution

Multiple optimal solution refers to a solution in which optimal objective function value can be generated from more than one solution. It is also termed as alternative optimal solution.

A solution can be have multiple solution if it satisfies the following two conditions,

(a) Constraint which creates the limits for feasible solutions region must be equal to slope of the objective function.

(b) Constraint should be active and create boundary on feasible region in optimal movement direction of objective function. Active constraint pass through one of the extreme points of feasible solution space.

Exercise Problems

1. A mining company is taking a certain kind of ore from two mines X and Y. The ore is divided into 3 quality groupsT B and C. Every week the company has to supply 240 tonnes of A, 160 tonnes of B and 440 tonnes of C. The cost per day for running the mine X is Rs. 3000, while it is Rs. 2000 for the mine Y. Each day, X will produce 60 tonnes of A, 20 tonnes of B and 40 tonnes of C. The corresponding figures for Y are 20,20 and 80.

   Develop the most economical production plan by finding the number of days for which the mines X and Y should work per week.

   [Ans : cost = Rs. 18000/-]

2. A person requires 10, 12 and 12 units of chemicals A, B and C respectively for his gardens. A liquid product contains 5,2 and 1 units of A, B and C respectively per jar. A dry product contains 1, 2 and 4 units ofA, B and C per carton. If the liquid product sells for Rs. 3 per jar and the dry product sells for Rs. 2 per carton, how many of each should be purchased to minimize the cost and meet the requirements? Formulate the above problem as a LPP and solve it by graphical method.

   [Ans : cost = Z_{min} = Rs. 13]

3. A company has two botding plants, one located at Bangalore and the other at Mysore. Each plant produces three brands of drinks A, B and C. Bangalore plant can produce (in one day) 1500, 3000 and 2000 bottles of A, B and C respectively. The capacity of Mysore plant remains, 1500, 1000 and 5000 botdes per day of A, B and C respectively. A market survey indicates that during the month of April there will be demand of 20,000 botdes of A, 40,000 botdes of B and 44,000 botdes of C. the operating cost per day for the plant at Bangalore is Rs. 600/- while the operating cost per day for the plant at Mysore is Rs. 400/- For how many days each plant be run in April so as to minimize the production cost while still meeting the demand ?

   [Ans : cost of operation is Rs. 8800/-]

4. Hema Pens Ltd. produces two types of pens namely; Supermo(S) and Economy pens (E). The net profits on these types are Rs. 10/- and Rs. 6/- respectively. Raw material required for Supermo(S) is twice as that of Economy (E). The supply of raw materials is sufficient only for 1000 pens of E per day. Pen S requires a special nib and Pen E requires ordinary nib. There are 400 special nibs, 700 ordinary nibs available in stock. Formulate for the daily product mix so as to maximise the total profit of company.

   [Ans : Max $Z = 10x_J + 6x_2$;

   S.t. $\frac{x_1}{2} + x_2 \leq 1000$

   $x_1 \leq 400$;

   $x_2 \leq 700$

   $x_1, x_2 \geq 0$ **and integers]**

5. Minimize $Z = 30x_1 + 20x_2$;

Subject to $x_1 + x_2 \leq 12$

$6x_1 + 8x_2 \geq 20$

$x_1 \leq 6$

and $x_1 + x_2 \geq 0$

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6. Minimise $Z = 2000x_1 + 3000x_2$

Subject to $6x_1 + 9x_2 \leq 100$

$2x_1 + x_2 \leq 0$

$x_1, x_2 \geq 0$

---

7. Maximise $Z = 6x_1 + 7x_2$

$6x_1 + 2x_2 \geq 24$

$2x_1 + 2x_2 \geq 16$

$x_1, x_2 \geq 0$

Short Question & Answers

1. What is Linear Programming Problem?

Ans :

In 1947, George dantzig and his associates, while working in the U.S. department of Air Force, observed that a large of military programming and planning problems could be formulated as maximizing/minimizing a linear form of profit/cost function whose variables were restricted to values satisfying a system of linear constraints.

A linear form is meant a the matically expression of the type $a_1x_1 + a_2x_2 + ... + a_nx_n$, where $a_1, a_2, ..., a_n$ are constants and $x_1, x_2, ..., x_n$ are variables. The term 'Programming' refers to the process of determining a particular programme or plan of action. So Linear Programming (L.P.) is one of the most important optimization (maximization/ minimization) techniques developed in the field of Operations Research.

2. Operation Research.

Ans :

Introduction

The term, operations research was first coined in 1940 by McClosky and Trefthen in a small town Bowdsey, of the United Kingdom. This new science came into existence in a military context. During world war II, military management called on scientists from various disciplines and organized them into teams to assist in solving strategic and tactical problems, relating to air and land defence of the country.

Hence OR can be associated with "an art of winning the war without actually fighting it."

Definitions

1. **According to Morse and Kimbal (1946)** OR is a scientific method of providing executive departments with a quantitative basis for decision regarding the operations under their control.
2. **According to P.M.S. Blackett (1948)** OR is a scientific method of providing executive with an analytical and objective basis for decisions.
3. **According to P.M. Morse (1948)** The term 'OR' has hitherto-fore been used to connate various attempts to study operations of war by scientific methods. From a more general point of view, OR can be considered to be an attempt to study those operations of modern society which involved organizations of men or of men and machines.
4. **According to Churchman, Acoff, Aritoff (1957)** OR is the application of scientific methods, techniques and tools to problems involving the operations of systems so as to provide these in control of the operations with optimum solutions to the problem.
5. **According to T. L .Saaty (1958)** OR is the art of giving had answers to problems to which otherwise worse answers are given.

3. Nature of operations research.

Ans :

- The term "Operations Research" refers to the application of scientific methodology of several different disciplines to problems related to the functioning or operating of some unit business, government or institutions.
- The operations research are expected by managers to analyze the management problems which involve the operations of systems, to gather essential data and to interpret those data.
- Operation Research specialist help the managers to make better decisions.
- It may provide top-level administrators with a quantitative basis for decisions that will increase the effectiveness of such organisations in carrying out their basic purpose.
- All operational level, O.R. provides scientific rates of decision making.

4. Limitations of OR

Ans :

1. Magnitude of Computation

Operations research tries to find out the optimal solution taking all the factors in to account. In the modern society these factors are numerous and expressing them in quantity and establishing, relationships among these requires huge calculations. All these calculations cannot be handled manually, but require electronic computes which bear very heavy cost. Thus, the use of OR is limited to very large organizations.

2. Absence of Quantification

Operations research provides solution only when all the elements related to a problem can be quantified. The tangible factors such as price product, etc., can be expressed in terms of quantity, but intangible factors such as human relations, etc., cannot be quantified. Thus, these intangible elements of the problem are excluded from the study, though these might be equally or more important than quantifiable elements. Now a days, attempts are being made to quantify even the intangible factors as far as possible

3. Distance between Managers and Operation Research

Operations research being specialists' job, requires mathematician or statistician who might not be aware of the business problems. Similarly, a manager fails to understand the complex working of OR.

5. Advantages of linear programming.

Ans :

1. Linear programming technique helps us in making the optimum utilization of productive resources. It also indicates how a decision maker can employ his productive factors most effectively by choosing and allocating these resources.
2. The quality of decisions may also be improved by linear programming techniques. The user of this technique becomes more objective and less subjective.
3. Linear programming technique provides practically applicable solutions since mere might be other constraints operating outside the problem which must also be taken into consideration just because, so many units must be produced does not mean that all those can be sold. So the necessary modification of its mathematical solution is required for the sake of convenience to the decision maker.
4. In production processes, high lighting of bottlenecks is the most significant advantage of this technique.

6. Discuss Mathematical Model of LPP.

Ans :

In order to find the values of n decision variables $x_1, x_2, ..., x_n$ to maximize or minimize the objective function

$$z = c_1x_1 + c_2x_2 + c_3x_3 + ... + c_nx_n$$

and also satisfy m-constraints :

$$\left.\begin{array}{l} a_{11}x_1 + a_{12}x_2 + ... + a_{1j}x_j + ... + a_{1n}x_n \ (\leq \text{or} \geq)\ b_1 \\ a_{21}x_1 + a_{22}x_2 + ... + a_{2j}x_j + ... + a_{2n}x_n \ (\leq \text{or} \geq)\ b_2 \\ \vdots \quad \vdots \quad \vdots \quad \vdots \quad \vdots \\ a_{i1}x_1 + a_{i2}x_2 + ... + a_{ij}x_j + ... + a_{in}x_n \ (\leq \text{or} \geq)\ b_i \\ \vdots \quad \vdots \quad \vdots \quad \vdots \quad \vdots \\ a_{m1}x_1 + a_{m2}x_2 + ... + a_{mj}x_j + ... + a_{mn}x_n \ (\leq \text{or} \geq)\ b_m \end{array}\right\}$$

where constraints may be in the form of any inequality ($\leq$ or $\geq$) or even in the form of an equation (=) and finally satisfy the non-negativity restrictions

$$x_1 \geq 0,\ x_2 \geq 0,\ ...,\ x_j \geq 0,\ ...,\ x_n \geq 0.$$

7. Major assumptions of LPP.

Ans :

1. Proportionality : A primary requirement of linear programming problem is that the objective function and every constraint function must be *linear*. Roughly speaking, it simply means that if 1 kg of a product costs Rs. 2, then 10 kg will cost Rs. 20. If a steel mill can produce 200 tons in 1 hour, it can produce 1000 tons in 5 hours.

Intuitively, linearity implies that the product

of variables such as $x_1 x_2$, powers of variables such as x_3^2, and combination of variables such as $a_1x_1 + a_2 \log x_2$, are not allowed.

2. **Additivity :** Additivity means if it takes t_1 hours on machine G to make product a and t_2 hours to make product B, then the time on machine G devoted to produce A and B both is $t_1 + t_2$, provided the time required to change the machine from product A to B is negligible.

   Then additivity may not hold, in general. If we mix several liquids of different chemical composition, then the total volume of the mixture may not be the sum of the volume of individual liquids.

3. **Multiplicativity :** It requires :

   (a) It takes one hour to make a single item on a given machine, it will take 10 hours to make 10 such items.

   (b) The total profit from selling a given number of units is the unit profit times the number of units sold.

4. **Divisibility :** It means that the fractional levels of variables must be permissible besides integral values.

8. LPP by graphical method.

Ans :

Graphical method is a simple method to understand and also to use. This is effectively used in LPP's which involves only 2 variables. It gives the graphical representation of the solutions.

All types of solutions are highlighted in this method very clearly. The only drawback is that more the number of constraints, more will be the straight lines which makes the graph difficult to understand.

Characteristics

The following are the characteristics of graphical method of LPP :

1. Method is very simple and easy to understand.
2. Very sensitive analysis and can be illustrated very easily by drawing graphs.
3. Very easy to obtain optimal solution.
4. It consumes very less time.

9. What are the merits and demerits of graphical method ?

Ans :

Merits

1. Graphical solutions are easier to understand and reproduce.
2. It is a pictorial view is always a better representattion.
3. A graphical solutions have gained prominence in Operations Research.

Demerits

However, graphical solutions have certain limitations such as :

1. Limited to the problems of two decision variables only.
2. Accuracy can not be obtained.
3. Some times it is difficult to represent certain expressions, particualy in the case of non linear expressions.

10. Multiple Optimal Solution.

Ans :

Multiple optimal solution refers to a solution in which optimal objective function value can be generated from more than one solution. It is also termed as alternative optimal solution.

A solution can be have multiple solution if it satisfies the following two conditions,

(a) Constraint which creates the limits for feasible solutions region must be equal to slope of the objective function.

(b) Constraint should be active and create boundary on feasible region in optimal movement direction of objective function. Active constraint pass through one of the extreme points of feasible solution space.

Choose the Correct Answers

1. The solution for an LPP with two exact constraints and no inequality constraints will be [d]

   (a) Infeasible (b) Unbounded

   (c) Multiple optimal (d) Unique point size solution

2. The feasible region will be _____ type if one of the constraints is exact type in a two variable LPP [b]

   (a) Point (b) Line

   (c) Area (d) Volume

3. In graphical solutions, if x is unrestricted and $y \geq 0$, we get the solution in _____ . [b]

   (a) 1st quadrant (b) 1st & 2nd quadrant

   (c) 1st & 4th quadrant (d) Any quadrant

4. In which of the following cases we do not maximise the objective function [d]

   (a) Sales (b) Profits

   (c) Contribution (d) Costs

5. If every point of a line drawn with any two points in feasible region fall in the feasible region the region is said to be [d]

   (a) Convex (b) Concave

   (c) Island (d) Infeasible

6. In an LPP, if the values given to the variable satisfy conditions and constraints but not the objective function, then the solution is [a]

   (a) Feasible solution (b) Optimal solution

   (c) Infeasible solution (d) We can not say

7. The feasible region in the form of a ring is _____ . [b]

   (a) Convex (b) Concave

   (c) Concavo-convex (d) Convexo-concave

8. The number of basic feasible solutions in a feasible region will be [a]

(a) Finite (b) Infinite

(c) Zero (d) We can not say

9. Which of the following models does not use probabilities. [d]

(a) Inventory models (b) Game theory models

(c) Queuing models (d) Linear programming

10. Which of the following belongs to Operations Research model classified on the basis of time reference. [c]

(a) Predictive model (b) Normative model

(c) Dynamic model (d) Simulation

11. In which of the following models, we do not use alphabet. [d]

(a) Mathematical model (b) Descriptive

(c) Verbal (d) None of the above

12. Deterministic models are based on [b]

(a) Time frame (b) Degree of certainty

(c) Method of solution (d) Nature or purpose of use

13. Iconic model uses [a]

(a) Scaled version (b) Expectation

(c) Synergy (d) Time reference

14. The Operations Research model represents a system, but does not physically resemble the components of the system is [b]

(a) Iconic (b) Analogue

(c) Symbolic (d) Normative

15. Game theory without saddle points belongs to _____ model of OR [d]

(a) Static (b) Dynamic

(c) Deterministic (d) Probabilistic

16. Replacement models when money value not changing with time can be considered as [a]

(a) Static (b) Dynamic

(c) Probabilistic (d) Simulative

17. Which of the following is not a strength of Operations Research. [d]

(a) Objective orientation (b) Distinct decision making

(c) Team approach (d) Gap between the user and OR model designer

18. Which of the following is not a limitation of Operations Research. [d]

(a) Qualitative aspects

(b) Gap between decision maker and model maker

(c) Involvement multiple constraints

(d) Scientific approach

19. The Operations Research widely employed in marketing problems is [b]

(a) Goal programming (b) Game theory

(c) Dynamic programming (d) Linear programming

20. Which of the following is not a part of an LPP problem [d]

(a) Objective function (b) Constraint set

(c) Condition set (d) End corrections

21. The availability constraint is represented with [b]

(a) $<$ (b) $\leq$

(c) $>$ (d) $\geq$

22. A constraint represented by '=' sign is [c]

(a) Availability, constraint (b) Requirement constraint

(c) Exact constraint (d) No constraint

23. If a maximum limit is imposed on a resource usage then it is known as [a]

(a) Availability constraint (b) Requirement constraint

(c) Exact constraint (c) Inside constraint

24. A product P contributes a profit of Rs. 50 and product Q contributes Rs. 60. This is represented in objective functions Z as _____ forxp and xQ products manufactured. [d]

(a) min. $Z = 50 x_P + 60 x_Q$ (b) max. $Z = 60 x_p + 50 x_Q$

(c) min. $Z = 60 x_p + 50 x_Q$ (d) max. $Z = 50 x_p + 60 x_Q$

Fill in the Blanks

1. The objective function in an LPP will be in the form of _____ or _____ .
2. The objective function chosen for an LPP when costs are given is _____ type.
3. A constraint, mathematically represented as ax + by = c is called _____ type constraint.
4. If a minimum limit is imposed on production of a certain commodity, the constraint is said to be _____ type.
5. The cost a product X is Rs. 5 per unit while that of product Y is Rs. 8 per unit. If x and y are the units to be manufactured, the objective function is _____ .
6. Krishna has Rs. 100 in his purse and went to a restaurant. He orders x_1 number of units of worth Rs. 10 each and x_2 number of units of worth Rs. 20 each. Then constraint is written as _____ .
7. The number of units of salt to put in a curry dish, to maximise its taste is a example for _____ type of constraint.
8. A company has to spend Rs. 200 per unit of advertisement in New paper whil Rs. 400 per unit in T.V. If the budget is Rs. 10,000 then the constraint is writte as _____ .
9. Product M costs Rs. 10 and product N cost Rs. 40 per unit manufactured. Th profit contribution are Rs. 50 and 30 respectively. The objective function is _____ .
10. If a convex set of feasible solutions of an LPP is a bounded solution space then its extreme points are said to be _____ solution.
11. If a convex set of feasible solution of an LPP is a bounded feasible region then it will have at least one _____ solution.
12. _____ solution is nothing to do with objective function of LPP.
13. _____ constraint has no effect on feasible region
14. A solution is said to be _____ if it satisfies the conditions, constraints and objective function
15. Any set of values, which satisfy the conditions of LPP is a _____ .
16. Graphical solutions are limited to the problems with _____ variables only.
17. If multiple optimal solution exists to an LPP, at least one of the constraints will have same slope as that of _____ .
18. If an LPP has infinite number of solutions, it is said to have _____ solution.

ANSWERS

1. Maximisation, Minimisation
2. Minimisation
3. Exact or equality
4. Requirement
5. min. $Z = 5x_1 + 8x_2$
6. $10 x_1 + 20 x_2 \leq 100$
7. Availability or $\leq$
8. $200x_1 + 400x_2 \leq 10000$
9. max. $z = 40x_1 - 10x_2$
10. basic feasible
11. optimal
12. infeasible
13. redundant
14. optimal
15. solution
16. two
17. objective function
18. unbounded

UNIT V

TRANSPORTATION, ASSIGNMENT AND QUEUING THEORY :

Transportation Problem (TP) - Mathematical model, IBFS using North West Corner Rule, Least Cost Method (LCM) and Vogel's Approximation Method(VAM).

Assignment Problem (AP): Mathematical model, method of obtaining solution- Hungarian method. Queuing Theory - Concepts of Queue - General structure of a Queuing system- Operating Characteristics of Queues.

5.1 TRANSPORTATION PROBLEM (TP)

5.1.1 Mathematical Model

Q1. What is a transportation problem? Give a mathematical formulation of the transportation.

Ans :

Meaning

Transportation problem is another case of application to linear programming problems, where some physical distribution (transportation) of resources is to be made from one place to another to meet certain set of requirements with in the given availability. The places from where the resources are to be transferred are referred to as sources or origins. These Sources (or) origins will have the availability or capacity (or) supply of resources. The other side of this transportation i.e. to where the resources are transported are called sinks (or) destinations such as market centres, godowns etc. These will have certain requirements or demand.

For example, a tyre manufacturing concern has m factories located in m different cities. The total supply potential of manufactured product is absorbed by n retail dealers in n different cities of the country. Then, transportation problem is to determine the transportation schedule that minimizes the total cost of transporting tyres from various factory locations to various retail dealers.

Mathematical Formulation

Let there be m origins, jth origin possessing a, units of a certain product, whereas there are n destinations (n may or may not be equal to m) with destination j requiring bj units. Costs of shipping of an item from each of m origins (sources) to each of the n destinations are known either directly (or) indirectly in terms of mileage, shipping hours, etc. Let c_{ij} be the cost of shipping one unit product from jth origin (source) to jth destination., and 'X_{ij}' be the amount to be shipped from jth origin to the destination.

It is also assumed that total availabilities Σa_i satisfy the total requirements Σb_j, i.e.,

$$\Sigma a_i = \Sigma b_j \ (i = 1,2, ..., m; j = 1,2,...,n) \quad ...(1)$$

In case, $\Sigma a_i \neq \Sigma b_j$ some manipulation is required to make $\Sigma a_i = \Sigma b_j$, which will be shown later).

The problem now is to determine non-negative (≥ 0) values of 'x_{ij}' satisfying both, the availability constraints:

$$\sum_{j=1}^{n} x_{ij} = a_i \quad \text{for } i = 1,2,...,m \quad ...(2)$$

as well as the requirement constraints :

$$\sum_{j=1}^{m} x_{ij} = x_{ij} = b_j \quad \text{for } j = 1,2,...,n \quad ...(3)$$

and minimizing the total cost of transportation

$$z = \sum_{i=1}^{m} \sum_{j=1}^{n} x_{ij} \ c_{ij} \quad \text{(objective function)} \quad ...(4)$$

Q2. What are the assumptions of transportation problem

Ans :

(i) It is assumed that quantity availble at sources is equal to the quantity required at destinations.

(ii) Items are eqsily transported from source to destination.

(iii) Transportation cost per unit from source to destination is well known.

(iv) The main aim is to reduce total transportation cost for the whole organization.

(v) There is direct relationship between transportation cost of specific route and number of units shipped for that specific route.

5.1.2 IBFS using North West Corner Rule

Q3. What are the different methods of finding initial feasible solution. Discuss briefly about North West Corner method.

(OR)

Explain briefly north-west corner rule for transportation problem.

Ans : **(Dec-19, July-19, Imp.)**

The various methods to find IBFS for a TP are :

(a) North – west corner rule (NWCR)

(b) Least cost entry method (LCM)

(c) Vogel's Approximation method (VAM)

North – West Corner Rule (NWCR)

The simplest of the procedures used to generate an initial feasible solution is NWCM. It is so called because we begin with the north west or upper left corner cell of our transportation table. Various steps of this method can be summarized as under :

Step 1 : Select the north west (upper left-hand) corner cell of the transportation table and allocate as many units as possible equal to the minimum between available supply and demand requirement i.e., min (S_1, d_1).

Step 2 : Adjust the supply and demand numbers in the respective rows and columns allocation.

Step 3 : (a) If the supply for the first row is exhausted, then move down to the first cell in the second row and first column and go to step 2.

(b) If the demand for the first column is satisfied, then move horizontally to the next cell in the second column and first row and go to step 2.

Step 4 : If for any cell, supply equals demand, then the next allocation can be made in cell either in the next row or column.

Step 5 : Continue the procedure until the total available quantity is fully allocated to the cells as required.

PROBLEMS

1. Consider the following transportation problem

	Destination				
Source	**D_1**	**D_2**	**D_3**	**D_4**	**Total**
O_1	**1**	**2**	**1**	**4**	**30**
O_2	**3**	**3**	**2**	**1**	**50**
O_3	**4**	**2**	**5**	**9**	**20**
Total	**20**	**40**	**30**	**10**	**100**

Determine the initial feasible solution

Sol :

Step 1: Formulation : The given problem is already formulated, hence proceed to step 2.

Step 2: The given problem is to minimise i.e., Standard. (If it is not mentioned, it is understood as standard TP)

Step 3: Balancing : Since the row totals (100) equal to column totals (100), it is already a balanced TP.

Step 4: Allocation by NWCM

Iteration Tableau-1 :

	D_1	D_2	D_3	D_4	Supply
O_1	1	2	1	4	30
O_2	3	3	2	1	50
O_3	4	2	5	9	20
Demand	(20)	40	30	10	100 / 100

In the above TP table, the northwest corner cell is (C_{11}) or (O_1, D_1). In this cell we allocate as many units as possible. The availability at this source (O_1) is 30, but the requirement for the destination (D_1) is only 20. Therefore we can transfer only 20 units from O_1 to D_1 (20 < 30). Therefore O_1 will have 10 more units to supply to any destination other than D_1. And since the D_1 requirement is exhausted we delete this column (D_1) for next iteration while we adjust the supply of O_1 from 30 to 10.

Cell allocated (C_{11}) or (O_1, D_1)

No. of units allocated 20

Deletion for next iteration : D_1 column (exhausted for D_1)

Readjustment for O_1 row : 30 to 10 (As 20 units are allocated)

Cell cost of transportation : 20 × 1 = 20

Iteration Tableau-2 :

	D_2	D_3	D_4	Supply
O_1	2 (10)	1	4	(10)
O_2	3	2	1	50
O_3	2	5	9	20
Demand	~~40~~ 30	30	10	80 / 80

Allocated cell (C_{12}) is (O_1, D_2)

No. of units allocated is 10

Deletion for next iteration is O_1

Readjustment for D_2 : 40 to 30

Cost of transportation from O_1 to D_2

= 2 × 10 = 20

Iteration Tableau-3 :

	D_2	D_3	D_4	Supply
O_2	3 (30)	2	1	~~50~~ 20
O_3	2	5	9	20
Demand	30	30	10	70 / 70

Allocated cell (C_{22}) is (O_2, D_2)

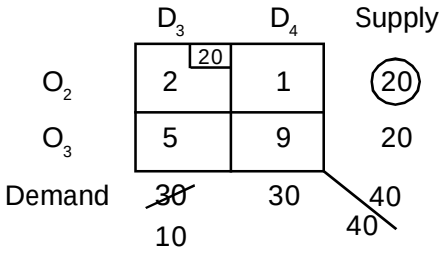
No. of units allocated is 30

Deletion for next iteration is D_2

Readjustment for O_2 is 50 to 20

Cost of transportation is 3 × 30 = 90

Iteration Tableau-4 :



Allocated cell (C_{23}) is (O_2, D_3)

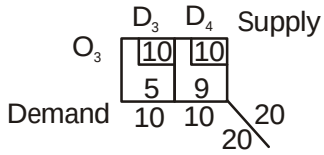
No. of units allocated is 20

Deletion for next iteration is O_2

Readjustment for D_3 is 30 to 10

Cost of transportation is 2 × 20 = 40

Iteration Tableau-5 :



Allocated cells (C_{33} and C_{34}) are (O_3, D_3) and (O_3, D_4)

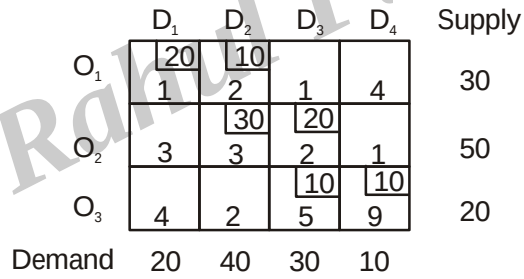
No. of units allocated are 10 and 10 respectively.

i.e., 50 and 90 respectively

All the units are exhausted

∴ IBFS is obtained

Summary :



Cost Calculations of IBFS by NWCM

Allocated Cell	From	To	Unit Cost	No. of Units	Total Cost
C_{11}	O_1	D_1	1	20	20
C_{12}	O_1	D_2	2	10	20
C_{22}	O_2	D_2	3	30	90
C_{23}	O_2	D_3	2	20	40
C_{33}	O_3	D_3	5	10	50
C_{34}	O_3	D_4	9	10	90
			Grand Total Cost of Transportation		310

Total cost of transportation = Rs. 310/-

2. Consider the following transportation problem

Source	Destination				
	D_1	D_2	D_3	D_4	Total
O_1	1	2	1	4	30
O_2	3	3	2	1	50
O_3	4	2	5	9	20
Total	20	40	30	10	100

Determine the initial feasible solution

Sol :

Let us solve using NWCM

Step 1:

The north west corner cell i.e., (O_1, D_1) is choosen

Step 2:

The minimum of supply and demand (30, 20) is 20. Allocate 20 units to cell (O_1, D_1)

Step 3:

Adjust supply and demand. Since, demand for first destination is exhausted move to cell (O_1, D_2).

Iteration Tableau-I

	D_1	D_2	D_3	D_4	Total
O_1	1 (20) →	2	1	4	~~30~~ 10
O_2	3	2	2	1	50
O_3	4	2	5	9	20
Total	~~20~~ 0	40	30	10	100

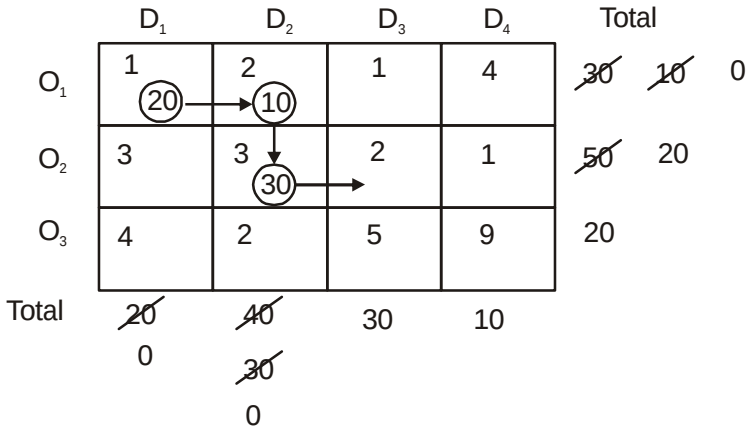
Step 4:

Repeat the procedure of allocation as in step 2 and step 3. Now cell O_1, D_2 is choosen. The minimum of supply and demand (10, 40) is 10. Allocate 10 units to cell O_1, D_2. Adjust the supply and demand.

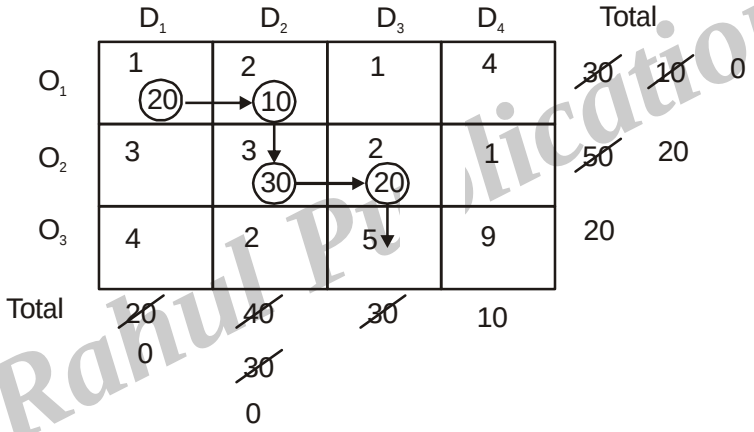
Iteration Tableau-II

	D_1	D_2	D_3	D_4	Total
O_1	1 (20) →	2 (10)	1	4	~~30~~ ~~10~~ 0
O_2	3	3 ↓	2	1	50
O_3	4	2	5	9	20
Total	~~20~~ 0	~~40~~ 30	30	10	

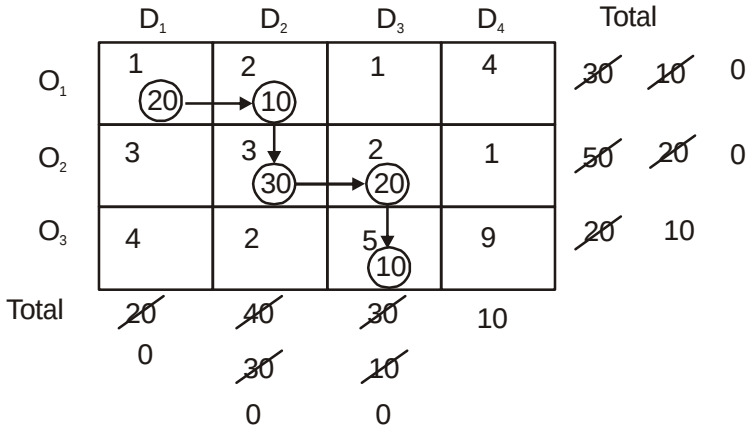
Iteration Tableau-III



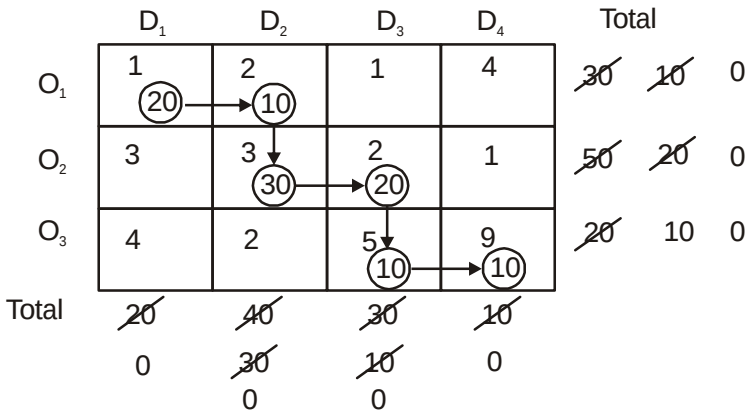
Iteration Tableau-IV



Iteration Tableau-V



Iteration Tableau-VI



Total cost of transportation = $\Sigma C_{ij}\, x_{ij}$

Where,

C_{ij} = Unit cost of transportation

x_{ij} = Number of units allocated.

= (1 × 20) + (2 × 10) + (3 × 30) + (2 × 20) + (5 × 10) + (9 × 10)

= 20 + 20 + 90 + 40 + 50 + 90 = ` 310

5.1.3 Least Cost Method (LCM)

Q4. What is Least Cost Method? Explain the steps involved in Least Cost Method to get initial basic feasible solution.

(OR)

Explain least cost method.

Ans : **(Dec.-20, July-19)**

Least cost method is also known as lowest cost entry method or matrix minima method. To achieve the objective of minimum transportation cost, this method consider those routes (or cells) with least unit transportation cost to transport the goods.

Steps

The steps of LCM are as follows,

Step-1

The cell with the smallest unit cost of transportation is chosen and as many units as possible are allocated to that cell. If there is a tie in the least cost, the cell where maximum allocation is possible is chosen.

Step-2

Adjust the supply and demand for the allocation made and eliminate (strike out) the row or column in which either supply or demand is exhausted. If both are exhausted simultaneously, both must be eliminated simultaneously.

Step-3

Repeat steps (1) and (2) with the next smallest unit cost of transportation among the remaining cells (uncrossed-out cells).

Step-4

Continue the procedure until the entire available supply at various sources and entire demand at various destinations are satisfied.

3. Consider the following transportation problem

Source	Destination				Total
	D_1	D_2	D_3	D_4	
O_1	1	2	1	4	30
O_2	3	3	2	1	50
O_3	4	2	5	9	20
Total	20	40	30	10	100

Determine the initial feasible solution

Sol :

Step-1

The cell with smallest unit cost is choosen. There are three cells with cost '1' i.e., (O_1, D_1), (O_1, D_3), (O_2, D_4). The cell with maximum allocation among the least cost cells is choosen.

Cell	Allocation
(O_1, D_1)	Min(30, 20) = 20
(O_1, D_3)	Min(30, 30) = (30) ← Max
(O_2, D_4)	Min(50, 10) = 10

The cell (O_1, D_3) is choosen for allocation of 30 units

Step-2

Adjust the supply and demand. Elimunate the row (or) column for which supply (or) demand is exhausted.

Iteration Tableau-I

	D_1	D_2	D_3	D_4	Total
O_1	~~1~~	~~2~~	~~1~~ (30)	~~4~~	~~30~~ 0
O_2	3	3	2	1	50
O_3	4	2	5	9	20
Total	20	40	~~30~~ 0	10	

Note

Since, both O_1 and D_3 are exhausted both are eliminated.

Step-3

Identify the least cost cell among the remaining cells i.e., uncrossed cells. Repeat steps with choosen cell until all the demand and supply are exhausted.

Iteration Tableau-II

	D_1	D_2	D_3	D_4	Total	
O_1	1	2	1 (30)	4	~~30~~	0
O_2	3	3	2	1 (10)	~~50~~	40
O_3	4	2	5	9	20	
Total	20	40	~~30~~ 0	~~10~~ 0		

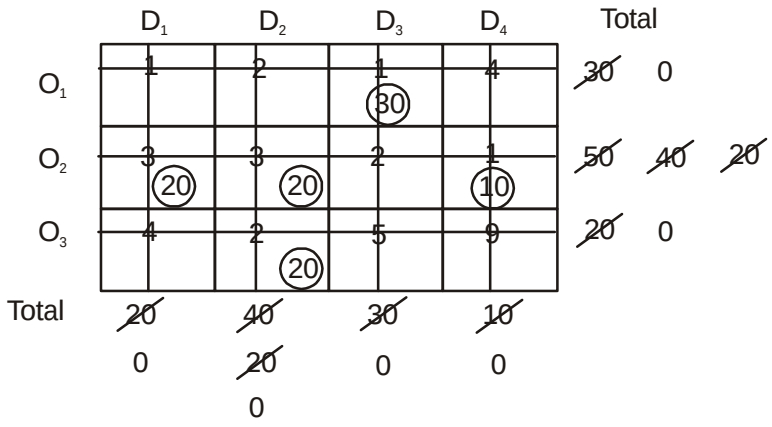
Iteration Tableau-III

	D_1	D_2	D_3	D_4	Total	
O_1	1	2	1 (30)	4	~~30~~	0
O_2	3	3	2	1 (10)	~~50~~	40
O_3	4	2 (20)	5	9	~~20~~	0
Total	20	~~40~~ 20	~~30~~ 0	~~10~~ 0		

Iteration Tableau-IV

	D_1	D_2	D_3	D_4	Total		
O_1	1	2	1 (30)	4	~~30~~	0	
O_2	3 (20)	3	2	1 (10)	~~50~~	~~40~~	~~20~~
O_3	4	2 (20)	5	9	~~20~~	0	
Total	~~20~~ 0	~~40~~ ~~20~~	~~30~~ 0	~~10~~ 0			

Iteration Tableau-V



Note

In tableau-IV, the least cost cells are (O_2, D_1) and (O_2, D_2). The allocations in these cells are (20, 20) respectively. As there is tie in not only in least cost cells but also in maximum possible allocation, the choice was made arbitarity.

Total cost of transportation = $\Sigma C_{ij} x_{ij}$

= (1 × 30) + (3 × 20) + (3 × 20) + (1 × 10) + (2 × 20)

= 30 + 60 + 60 + 10 + 40

= ` 200

5.1.4 Vogel's Approximation Method (VAM)

Q5. What is Vogels Approximation Method (VAM)? Explain the steps to get an initial basic feasible solution by Vogels Approximation Method

Ans : **(July-19)**

VAM or Vogel's Approximation Method is also known as penalty or regret method. It is basically a heuristic method. Allocation is done on the basis of opportunity cost (penalty) that would have incurred if allocation in certain cells with minimum costs were missed.

The steps involved in this method for finding the initial solution are as follows.

Step 1

Find the penalty cost, namely the difference between the smallest and next smallest costs in each row and column.

Step 2

Among the penalties as found in step (1) choose the maximum penalty. If this maximum penalty is more than one (i.e if there is a tie) choose any one arbitrarily.

Step 3

In the selected row or column as by step (2) find out the cell having the least cost. Allocate to this cell as much as possible depending on the capacity and requirements.

Step 4

Delete the row or column which is fully exhausted. Again compute the column and row penalties for the reduced transportation table and then go to step (2) Repeat the procedure until all the rim requirements are satisfied.

Note If the column is exhausted, then there is a change in row penalty and vice versa.

PROBLEMS

4. A company has factories at F1, F2 and F3 which supply warehouses at W1, W2 and W3. Weekly factory capacities are 200, 160 and 90 units respectively. Weekly warehouse requirements are 180, 120 and 150 units respectively. Unit shipping costs (in rupees) are as follows,

	Warehouse			
Factory	W1	W2	W3	Supply
F1	16	20	12	200
F2	14	8	18	160
F3	26	24	16	90
Demand	180	120	150	450

Determine the optimum distribution for this company to minimize shipping costs.

Sol :

		Warehouse			
		W_1	W_2	W_3	Supply
Factories	F_1	16	20	12	200
	F_2	14	8	18	160
	F_3	26	24	16	90
Demand		180	120	120	450

IBFS using VAM

	W_1	W_2	W_3	Supply	RP_1	RP_2	RP_3	RP_4
F_1	16 (140)	20	12 (60)	~~200~~ ~~140~~ 0	4	4	4	16 ←
F_2	14 (40)	8 (120)	18	~~160~~ ~~40~~ 0	6	4	4	14
F_3	26	24	16 (90)	~~90~~ 0	8	10 ←	–	
Demand	~~180~~ ~~40~~ 0	~~120~~ 0	~~150~~ ~~60~~ 0	450				

	CP_1	2	12↑	4
Penalty	CP_3	2	–	4
	CP_3	2	–	6↑
	CP_4	2	–	–

Optimal Distribution / Allocation

For Factory F_1

$X_{11} = 140, X_{12} = 0, X_{13} = 60$

For Factory F_2

$X_{11} = 40, X_{23} = 120, X_{23} = 90$

For Factory F_3

$X_{11} = 0, X_{32} = 0, X_{33} = 90$

Total transportation cost is,

$= (16 \times 140) + (12 \times 60) + (14 \times 40) + (8 \times 120) + (16 \times 90)$

$= ` 2240 + 720 + 560 + 960 + 1440 = ` 5920.$

5. Consider the following transportation problem. Determine the initial feasible solution.

Source	Destination				Total
	D_1	D_2	D_3	D_4	
O_1	1	2	1	4	30
O_2	3	3	2	1	50
O_3	4	2	5	9	20
Total	20	40	30	10	100

Sol :

Vogel's Approximation Method (VAM)

Step 1:

Compute row and column penalties by taking the difference between the smallest and next smallest unit cost in each row and each column.

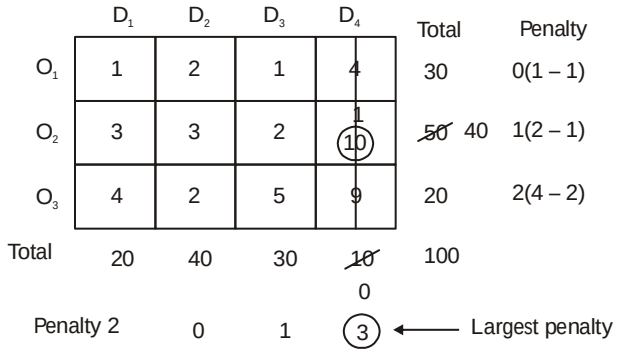
Step 2:

Choose the row or column with largest penalty and make allocations to the least cost cell in that row or column

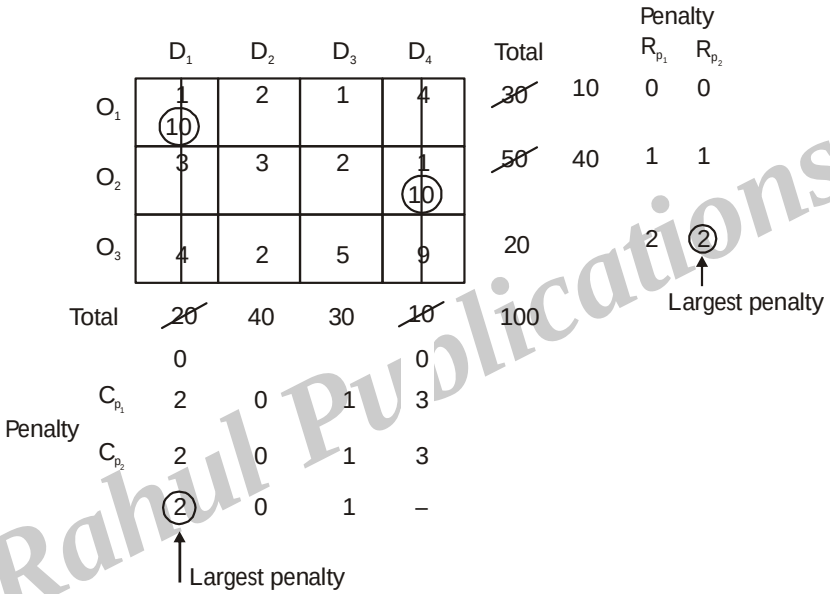
Step 3:

Adjust the supply and demand. Eliminate the row or column which is exhausted.

Iteration Tableau-I



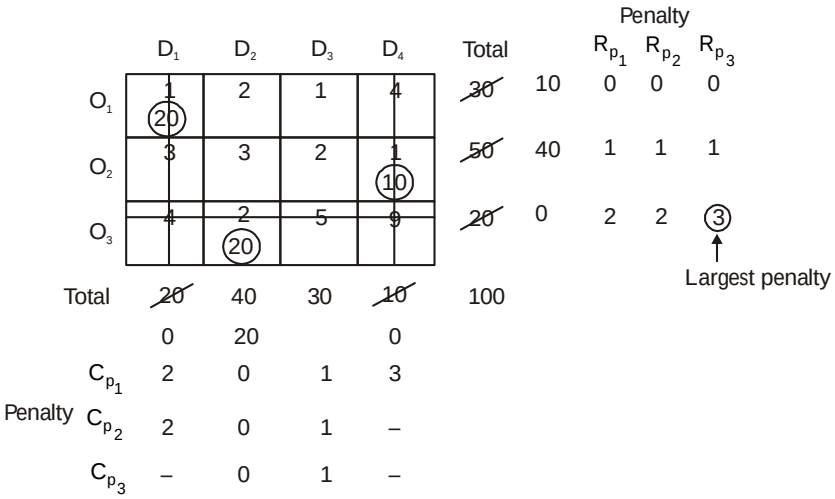
Iteration Tableau-II



Note

Tie in largest penalty. Choice is made based on least cost cell i.e., column I.

Iteration Tableau-III

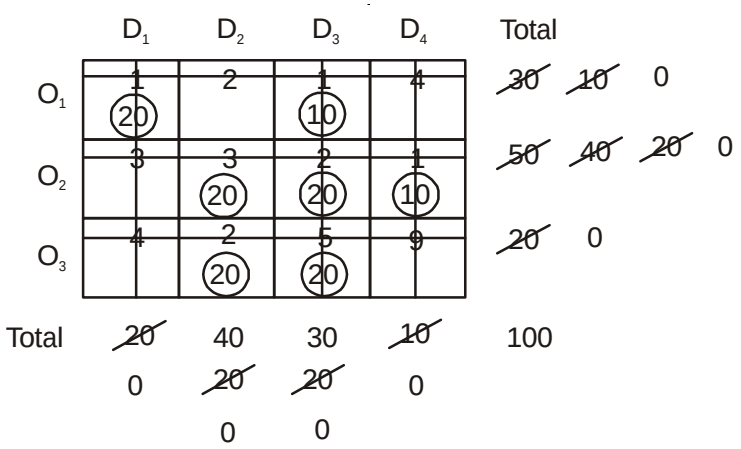


Iteration Tableau-IV

	D_1	D_2	D_3	D_4	Total		Penalty R_{p_1}	R_{p_2}	R_{p_3}	R_{p_4}
O_1	1 (20)	2	1 (10)	4	~~30~~	10 0	0	0	1	(1)
O_2	3	3	2	1 (10)	~~50~~	40	1	1	1	(1)
O_3	4	2 (20)	5	9	~~20~~	0	2	2	3	–
Total	~~20~~	40	30	~~10~~	100					
	0	20	20	0						
C_{p_1}	2	0	1	3						
Penalty C_{p_2}	2	0	1	–						
C_{p_3}	–	0	1	–						
C_{p_4}	–	(1)	(1) ↑	–						

Iteration Tableau-V

	D_1	D_2	D_3	D_4	Total		Penalty R_{p_1}	R_{p_2}	R_{p_3}	R_{p_4}	R_F
O_1	1 (20)	2	1 (10)	4	~~30~~	~~10~~ 0	0	0	1	1	–
O_2	3	3 (20)	2	1 (10)	~~50~~	~~40~~ 0	1	1	1	1	1
O_3	4	2 (20)	5	9	~~20~~	0	2	2	3	–	–
Total	~~20~~	40	30	~~10~~	100						
	0	~~20~~	20	0							
C_{p_1}	2	0	1	3							
Penalty C_{p_2}	2	0	1	–							
C_{p_3}	–	1	1	–							
C_{p_4}	–	(3) ↑	2	–							



Only left out cell (O_2, D_3) make the allocation of balance 20 units.

Total transportation cost = $\Sigma C_{ij}\, x_{ij}$

= (1×20) + (1×10) + (3×20) + (2×20) + (1×10) + (2×20)

= 20 + 10 + 60 + 40 + 10 + 40 = ` 180

6. The Amulya Milk Company has three plants located throughout a state with production capacity 50, 75 and 25 gallons. Each day firm must furnish its four retail shops R_1, R_2, R_3 and R_4 with at least 20, 20,50 and 60 gallons respectively.

Plant	Retail Shop				Supply
	R_1	R_2	R_3	R_4	
P_1	3	5	7	6	50
P_2	2	5	8	2	75
P_3	3	6	9	2	25
Demand	20	20	50	60	

The economic problem is to distribute the available product to different retail shops in such a way so that the total transportation cost minimum.

Sol : **(Dec.-18)**

Starting from the north west corner we allocate min (50,20) to P_1 R_1 i.e. 20 units to cell P_1 R_1. The demand for the first column is satisfied the allocation is shown in following table .

Plant	Retail shop				Supply
	R_1	R_2	R_3	R_4	
P_1	20	5	7	6	50 30
P_2	2	5	8	2	75
P_3	3	6	9	2	25
Demand	20	20	50	60	

Now we move horizontally to the second column in the first row and allocate 20 units to cell $P_1 R_2$ The demand for the second column is also satisfied.

Plant	Retail shop				Supply
	R_1	R_2	R_3	R_4	
P_1	20 3	20 5	7	6	~~50~~ ~~30~~ 10
P_2	2	5	8	2	75
P_3	3	6	9	2	25
Demand	~~20~~	~~20~~	50	60	

Proceeding in this way, we observe that $P_1R_3 = 10$, $P_2 R_3 = 40$, $P_3 R_4 = 25$.

The Resulting feasible solution is shown in following table.

Plant	Retail shop				Supply
	R_1	R_2	R_3	R_4	
P_1	20 3	20 5	10 7	6	~~50~~
P_2	2	5	40 8	35 2	~~75~~
P_3	3	6	9	25 2	~~25~~
Demand	~~20~~	~~20~~	~~50~~	~~60~~	

Here the number of Retail shops n = 4 and No. of plants (m) = 3

No. of basic variables = m + n – 1

3 + 4 – 1 = 6

No. of basic variables = m + n – 1

3 + 4 – 1 = 6

Initial basic feasible solution

The total transportation cost is calculated by multiplying each x_{ij} in an occupied cell with the corresponding C_{ij} and adding as follows

20 × 3 + 20 × 5 10 × 7 + 40 × 8 + 35 × 2 + 25 × 2

60 + 100 + 70 + 320 + 70 + 50

= 670

5.2 ASSIGNMENT PROBLEM (AP)

Q6. Define Assignment Problem.

(OR)

What is an Assignment Problem?

Ans :

The name 'Assignment Problem' originates from the classical problems where the objective is to assign a number of origins (jobs) to the equal number of destinations (persons) at a minimum cost (or maximum profit). To examine the nature of assignment problem, suppose there are n jobs to be performed and n persons are available for doing these jobs. Assume that each person can do each job at a time, though with varying degree of efficiency. Let C_{ij} be the cost (payment) if the ith person is assigned the jth job, the problem is to find an assignment (which job should be assigned to which person) so that the total cost for performing all jobs is minimum. Problems of this kind are known as assignment problems.

Jobs

Persons	I	2	...	j	...	n
1	C_{11}	C_{12}	...	C_{ij}	...	C_{1n}
2	C_{2I}	C_{22}	...	C_{2j}	...	C_{2n}
:	:	:				:
i	C_{i1}	C_{i2}	...	C_{ij}	...	C_{in}
:	:	:		:		:
n	C_{n1}	C_{n2}	...	C_{nj}	...	C_{nn}

Table.: Assigment Problem

Further, such types of problems may consist of assigning men to offices, classes to rooms, drivers trucks, trucks to delivery routes (or) problems toxesearch teams etc.. The assignment problem can be stated the form of n × n cost-matrix $[c_{ij}]$ of real number.

5.2.1 Mathematical Model

Q7. Give the Mathematical formulation of an assignment problem.

Ans :

Mathematically, the assignment problem can be stated as :

Minimize the total cost : $z = \sum_{i=1}^{n} \sum_{j=1}^{n} C_{ij} X_{ij}$, i = 1, 2,.... ,n ; j = 1, 2,...,n ...(1)

subject to restrictions of the form :

$$x_{ij} = \begin{cases} 1 \text{ if ith person is assigned jth job} \\ 0 \text{ if not n} \end{cases} \quad ...(2)$$

$$\sum_{j=1}^{n} x_{ij} = 1 \text{ (one job is done by the ith person, i = 1,2, ... , n)} \quad ...(3)$$

and $\sum_{i=1}^{n} x_{ij} = 1$ (only one person should be assigned the jih job, j = 1,2, ... ,n) ...(4)

where x_{ij} denotes that jth job is to be assigned to the ith person.

This special structure of assignment problem allows a more convenient method of solution in comparison to simplex method.

Q8. Formulate an assignment problem as a linear programming problem. Why do you need to have a separate technique to solve this problem rather than using simplex technique.

Ans : **(Dec-19)**

The basic purpose behind the classical Assignment Problem (AP) is to allocate jobs to the competent workers based on their skills and competencies. However, while allocating the jobs, the manager must focus on its principal goal of minimizing the cost associated with the assignment of workers to jobs. Consider 'n' workers and jobs whose assignment matrix can be formed as follows,

Jobs (b)

workers (a)	1	2	3	4	5	.....	n
1	c_{11}	c_{12}	c_{13}	c_{14}	c_{15}	.....	c_{1n}
2	c_{21}	c_{22}	c_{23}	c_{24}	c_{25}	.....	c_{2n}
3	c_{31}	c_{32}	c_{33}	c_{34}	c_{35}	.....	c_{3n}
4	c_{41}	c_{42}	c_{43}	c_{44}	c_{45}	.....	c_{4n}
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
n	c_{n1}	c_{n2}	c_{n3}	c_{n4}	c_{n5}	.....	c_{nn}

The element C_{ab} represents the unit cost of assigning a^{th} worker with b^{th} job. Wherein a and b = 1,2,3,4 .... n.

Assignment model is established based on an assumption that both the number of workers and the number of jobs are equal i.e., each job is assigned to each worker.

Q9. Explain the various types of converting maximization problem into minimization assignment problem.

Ans : **(Dec.-18)**

Assignment Problems (APs) where the objective function is maximization of profit, revenue, returns etc., are called maximization problems.

The two types or ways or methods of converting maximization AP into minimization AP are,

I. Subtraction of all the Elements of Payoff Matrix from the Largest Element of that Matrix

The two steps involved in this method of conversion are,

Step-1

Identify the largest/highest payoff element in the assignment matrix.

Step-2

Subtract each of the elements of the matrix from the identified largest/highest payoff element.

II. Put Minus Sign Before Each Element of the Payoff Matrix

An another way/method of converting maximization AP into hominization AP is putting a negative sign before each element of the profit matrix.

5.2.2 Method of Obtaining Solution

Q10. What are the different methods of Obtaining Solution in assignment problem?

Ans :

1. Complete Enumeration Method

Complete enumeration method is a method used for solving assignment problem wherein a list is prepared of possible assignments and assignment with minimum cost or maximum profit is selected. The selected assignment is considered as optimal solution. If there are more assignments with same least cost then it is said that problem has multiple optimum solution. This method is not appropriate for real world situations.

2. Transportation Method

Assignment problem is referred as classical transportation problem. By applying transportation method, solution can be obtained easily but it will degenerate. Hence, optimally test is necessary in transportation method wherein basic variables should be m+n-1. This method can be proceeded by introducing large number of epsilons in the solution.

3. Simplex Method

An assignment problem can be formulated in the form of transportation problem which is nothing but a special case of LPP. An assignment problem can be formulated in linear programming problem with the help of integer variables and by using modified simplex method. In formulation, decision variables are needed either 1 or 0 based on assignment is made or not. It is relatively difficult to solve the assignment problem in LPP format. Hence, this approach is not regarded as appropriate.

4. Hungarian Assignment Method (HAM)

All the three methods are not so efficient in solving an assignment problem. Hungarian method is the only method specifically made to solve assignment problems in an effective way. This method is based on opportunity cost concept. If a problem has objective function of the maximization type then it is converted into minimization type.

Q11. Write a brief note on unbalanced assignment problem (AP).

Ans : **(July-19)**

An assignment problem is said to be unbalanced if the number of rows is not equal to the number of columns. Number of rows n(r) = Number of columns n(c) balanced AP. Number of rows n(4) $\neq$ number of column n(c) unbalanced AP.

The AP is balanced if the AP matrix is a square and unbalanced if it is not a square matrix.

In unbalanced AP, we notice that either number of jobs are greater or lesser than number of men or machine. In such case, a dummy row/column will be created with zero costs to each cell. Observe the following example to convert unbalanced AP to balanced AP.

	M_1	M_2	M_3
J_1	x_{11}	x_{12}	x_{13}
J_2	x_{21}	x_{22}	x_{23}
J_4	x_{31}	x_{32}	x_{33}
J_5	x_{41}	x_{42}	x_{43}

Unbalanced :
Machines (3) ≠ jobs (4)

	M_1	M_2	M_3	Dummy
J_1	x_{11}	x_{12}	x_{13}	0
J_2	x_{21}	x_{22}	x_{23}	0
J_4	x_{31}	x_{32}	x_{33}	0
J_5	x_{41}	x_{42}	x_{43}	0

Balanced :
Machines (4) = jobs (4) here D is Dummy machine.

Similarly, if jobs are less, we create a dummy row with zero costs.

5.2.2.1 Hungarian Method

Q12. Explain the Hungarian Method to solve assignment problem.

(OR)

Discuss the steps involved in the Hungarians Method used to find optimal solution to an Assignment Problem.

Ans : **(Imp.)**

Steps Involved in the Hungarian Method (in Solving Minimization Problems)

Step 1

Check whether the numbers of rows are equal to the number of column. If the number of rows equals the number of columns, the problem is a balanced one and Hungarian method can be used. If not, then the assignment problem is unbalanced and application of Hungarian method to an unbalanced problem yields an incorrect solution. Hence any assignment problem should be balanced by the additions of one or more dummy points (i.e., rows and columns). For dummy rows and columns, the value at the point of intersection of row and column is of zero value (i.e., zero cost in a cost matrix)

Step 2

Find the minimum element (or cost) in each row of the (m x m) cost matrix. Construct a new matrix by subtracting from each cost the minimum cost in its row. For this new matrix, find the minimum cost in each column. Construct a new matrix (called the reduced cost matrix) by subtracting from each cost, the minimum cost in its column.

This step may also be stated as below:

(a) Row Subtraction : Subtract the minimum element (say cost) of each row from all elements in that row. (Note : If there is zero in each row, there is no need for row subtraction).

(b) Column Subtraction : Subtract the minimum element of each column (of the new matrix obtained after row subtraction) from all elements of that column (Note : if there is zero in each column, there is no need for column subtraction).

Step 3

Draw the minimum number of lines (horizontal, vertical or both) that are needed to cover ail the zeros in the reduced cost matrix. If 'm' lines are required then an optimal solution is available among the covered zeros in the matrix. If fewer than 'm' lines are needed, then proceed to Step 4.

[**Note :** To draw the minimum number of lines the following procedure may be followed:

(a) Select a row containing exactly one uncovered zero and draw a vertical line through the column containing this zero and repeat the process till no such row is left.

(b) Select a column containing exactly one uncovered zero and draw a horizontal line through the row containing the zero and repeat the process till no such column is left].

Step 4 :

Find the smallest non-zero element (call its value K) in the reduced cost matrix that is uncovered by the lines drawn in Step 3. Now subtract K from each uncovered element of the reduced cost matrix and add K to each element that is covered by two lines.

Step 5 :

Repeat steps 3 and 4 till minimum number of lines covering ail zeros is equal to the size of the matrix (i.e., 'm' lines in a 'm x m' matrix)

Step 6 :

Assignment : Use the matrix obtained in Step 5 (without horizontal or vertical lines) select a row containing exactly one unmarked zero and surround it by a and draw a vertical line through the column containing this zero. Repeat the process till no such row is left, then select a column containing exactly one covered zero and surround it by a and draw a horizontal line through the row containing this zero and repeat this process till no such column is left.

[**Note :** if there are more than one unmarked zero in any row or column, it indicates that an alternative solution exists. In this case, select any one arbitrarily and pass two lines horizontally and vertically.]

Step 7 :

Add up the value attributable to the allocation which shall be the minimum value.

Step 8 :

Alternate solution : If there are more than one covered zero in any row or column, select the other one (i.e., other than the one selected in step 6) and pass two lines horizontally and vertically. Add up the value attributable to the allocation, which shall be the minimum value.

PROBLEMS

7. Solve the following assignment problem by Hungarian assignment method.

Time (in minutes)			
Worker	**Job 1**	**Job 2**	**Job 3**
A	**4**	**2**	**7**
B	**8**	**5**	**3**
C	**4**	**5**	**6**

Sol :

Given,

Time (in minutes)			
Worker	**Job 1**	**Job 2**	**Job 3**
A	**4**	**2**	**7**
B	**8**	**5**	**3**
C	**4**	**5**	**6**

Step 1

Row Reduced Matrix (Row Reduction)

Select the minimum number from each row and subtract it from each element of row.

Worker	**Job 1**	**Job 2**	**Job 3**
A	**2**	**0**	**5**
B	**5**	**2**	**0**
C	**0**	**1**	**2**

Step 2

Column Reduced Matrix (Column Reduction)

No need to do column reductions as each column is having a 'zero'.

Now, cover maximum zeros from the reduced matrix.

Worker	Job 1	Job 2	Job 3
A	~~2~~	[0]	~~5~~
B	~~5~~	2	[0]
C	[0]	1	2

Since, the number of assignments is equal to the order of matrix, the current solution is said to be optional.

Allocations are,

Worker A $\rightarrow$ Job 2 = 2

Worker B $\rightarrow$ Job 3 = 3

Worker C $\rightarrow$ Job 1 = 4

Minimum Cost 9

8. A company has 4 machines available for assignment to 4 tasks. Any machine can be assigned to any task, and each task requires processing by one machine. The time required to set up each machine for the processing of each task is given in the table below.

What kind of assignment will allow the company to minimize the total setup time needed for the processing of all four tasks?

	TIME (Hours)			
	Task 1	**Task 2**	**Task 3**	**Task 4**
Machine 1	**13**	**4**	**7**	**6**
Machine 2	**1**	**11**	**5**	**4**
Machine 3	**6**	**7**	**2**	**8**
Machine 4	**1**	**3**	**5**	**9**

Sol :

	TIME (Hours)			
	Task 1	**Task 2**	**Task 3**	**Task 4**
Machine 1	13	4	7	6
Machine 2	1	11	5	4
Machine 3	6	7	2	8
Machine 4	1	3	5	9

Step 1

Row Reduced Matrix (Row Reduction)

Select the minimum number from each row and subtract it from each element of row.

	Task 1	**Task 2**	**Task 3**	**Task 4**
Machine 1	9	0	3	2
Machine 2	0	10	4	3
Machine 3	4	5	0	6
Machine 4	0	2	4	8

Step 2

Column Reduced Matrix (Column Reduction)

Select the minimum number from each column and subtract it from each element of column.

	Task 1	Task 2	Task 3	Task 4
Machine 1	~~9~~	[0]	3	~~2~~
Machine 2	~~0~~	10	4	1
Machine 3	~~4~~	5	[0]	~~4~~
Machine 4	[0]	2	4	6

Step 3

Assignment

As number of assignment ≠ order of matrix. Thus applying Hungarian rule. The minimum cost uncovered element is '1'. So add '1' where the lines are intersecting and subtract '1' from all uncovered elements.

New Cost Matrix

	Task 1	Task 2	Task 3	Task 4
Machine 1	~~9~~	~~[0]~~	~~3~~	~~8~~
Machine 2	~~8~~	10	4	1
Machine 3	~~4~~	~~5~~	~~[0]~~	~~4~~
Machine 4	[0]	2	4	6

Step 4: Optimally Test

Number of assignments = 4

Number of row/columns = 4

Since, the number of assignments = Number of row/ columns

Therefore, the current solution is optimal.

Optimal Solution

Machine 1 $\rightarrow$ Task 2 = 4

Machine 2 $\rightarrow$ Task 4 = 4

Machine 3 $\rightarrow$ Task 3 = 2

Machine 4 $\rightarrow$ Task 1 = 1

Min. time = 11

$\therefore$ The minimum total setup time is 11 hours.

9. Solve the minimal assignment problem for the cost matrix given below :

	1	**2**	**3**	**4**
A	12	13	14	15
B	14	15	16	17
C	17	18	19	18
D	13	15	18	14

Sol :

Step 1 : Row Subtraction :

Subtract the smallest element in the row from each element in that row. The resulting cost matrix is shown:

	1	2	3	4
A	0	1	2	3
B	0	1	2	3
C	0	1	2	1
D	0	2	5	1

Step 2 : Column subtraction :

In the cost matrix obtained in Step 1 : subtract the smallest element in the column from each element in that column.

	1	2	3	4
A	0	1	2	3
B	0	1	2	3
C	0	1	2	1
D	0	2	5	1

The reduced cost matrix is as shown below :

	1	2	3	4
A	~~0~~	~~0~~	~~0~~	~~2~~
B	~~0~~	~~0~~	~~0~~	~~2~~
C	~~0~~	~~0~~	~~0~~	~~0~~
D	~~0~~	1	~~3~~	~~0~~

Since no signal zero exists in any row column we have the following alterative columns

(i)

	1	2	3	4
A	[0]	~~0~~	~~0~~	2
B	~~0~~	[0]	~~0~~	2
C	~~0~~	~~0~~	[0]	~~0~~
D	~~0~~	1	3	[0]

(ii)

	1	2	3	4
A	~~0~~	[0]	~~0~~	2
B	~~0~~	~~0~~	[0]	2
C	~~0~~	~~0~~	~~0~~	[0]
D	[0]	1	3	0

(iii)

	1	2	3	4
A	~~0~~	~~0~~	[0]	2
B	~~0~~	[0]	~~0~~	2
C	~~0~~	~~0~~	~~0~~	[0]
D	[0]	1	3	~~0~~

The possible optimal solutions are

		Cost (Rs)
(i)	A → 1 →	12
	B → 2 →	15
	C → 3 →	19
	D → 4 →	14
	Total	**60**

		Cost (Rs)
(ii)	A → 2 →	13
	B → 3 →	16
	C → 4 →	18
	D → 1 →	13
	Total	**60**

		Cost (Rs)
(iii)	A → 3 →	14
	B → 2 →	15
	C → 4 →	18
	D → 1 →	13
	Total	**60**

10. A department has five employees with five jobs to be performed. The time (in hours) each man will take to perform each job is given in the effectiveness material.

		Employees				
		I	II	III	IV	V
Jobs	A	10	5	13	15	16
	B	3	9	18	13	6
	C	10	7	2	2	2
	D	7	11	9	7	12
	E	7	9	10	4	12

How should the jobs be allocated, one per employee, so as to minimize the total man hours?

Sol : **(July-19)**

$$\begin{bmatrix} 10 & 5 & 13 & 15 & 16 \\ 3 & 9 & 18 & 13 & 6 \\ 10 & 7 & 2 & 2 & 2 \\ 7 & 11 & 9 & 7 & 12 \\ 7 & 9 & 10 & 4 & 12 \end{bmatrix}$$

Step 1

Row Reduced Matrix (Row Reduction)

Select smallest time from every row and substitute it from corresponding time, performs similar operations to the other Rows

$$\begin{bmatrix} 5 & 0 & 8 & 10 & 11 \\ 0 & 6 & 15 & 10 & 3 \\ 8 & 5 & 0 & 0 & 0 \\ 0 & 4 & 2 & 0 & 5 \\ 3 & 5 & 6 & 0 & 8 \end{bmatrix}$$

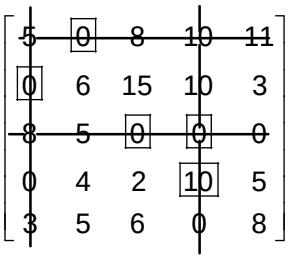
Step 2

Column Reduced Matrix (Column Reduction)

Select smallest time from every column and substitute it from corresponding time, performs similar operations to the other Rows

$$\begin{bmatrix} 5 & 0 & 8 & 10 & 11 \\ 0 & 6 & 15 & 10 & 3 \\ 8 & 5 & 0 & 0 & 0 \\ 0 & 4 & 2 & 0 & 5 \\ 3 & 5 & 6 & 0 & 8 \end{bmatrix}$$

Step – 3 (Assignment)



Step - 4 : Among smallest line is '2' odd and Subtract Respectively

Job					
1	7	0	8	12	11
2	0	4	13	10	1
3	10	5	x	2	0
4	9	2	0	x	3
5	3	3	4	0	6

Job	Employees	Time
1	II	5
2	I	3
3	V	2
4	III	9
5	IV	4
		23

11. Five men are available to do different jobs. The time that each person takes to do the job is given in the following table.

	Jobs				
Men	**1**	**2**	**3**	**4**	**5**
A	**2**	**8**	**2**	**8**	**1**
B	**5**	**6**	**8**	**5**	**1**
C	**4**	**5**	**4**	**3**	**1**
D	**4**	**2**	**6**	**3**	**1**
E	**5**	**9**	**7**	**5**	**1**

Find the assignment of men to jobs that will minimize the total time taken.

Sol : **(Dec.-20)**

Given Assignment problem is balanced

No. of Rows = No. of columns

5 = 5

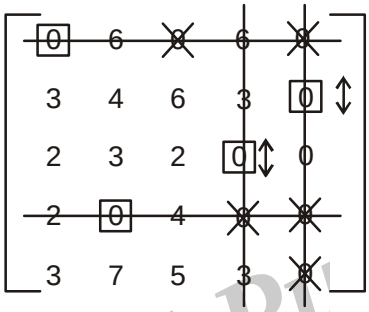
Step 1 : Row Subtraction :

1	7	1	7	0
4	5	7	4	0
3	4	3	2	0
3	1	5	2	0
4	8	6	4	0

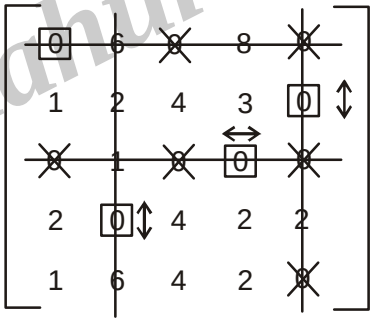
Step 2 : Column subtraction :

0	6	0	6	0
3	4	6	3	0
2	3	2	0	0
2	0	4	0	0
3	7	5	3	0

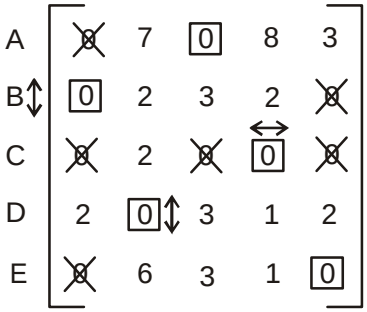
Step 3 : Making Assignments



Step 4 : Modified Matrix



Step 5 : Modified Matrix



6. Conclusion

Cost	Allocation
A – 3	2
B – 3	5
C – 4	3
D – 2	2
E – 5	1
Min cost	13

Q13. Distinguish between a Assignment problem and a Transportation problem.

Ans : **(Dec.-20, Imp.)**

S.No	Assignment Problem	S.No	Transportation Problem
1.	This problem is used to assign the jobs to machines or machines to men etc.	1.	This problem is used in transporting material from origins (like plant) to destinations (such as godown/market) etc.,
2.	No availability (supply) and requirement (demand) are needed to solve the problem.	2.	Supply & demand are needed.
3.	If number of rows is equal to no. of column the AP is said to be balanced otherwise unbalanced	3.	If supply is equal to demand the TP is said be balanced otherwise unbalanced
4.	There will not be any degeneracy in this problem.	4.	A possibility of degeneracy either at initial stage or subsequent stages may occur.
5.	This problem is solved by converting into opportunity costs (Hungarian method)	5.	This can be solved without converting the given costs (North west corner or Vogel's approximation or (least cost). In VAM we use penalities in LCM we use least cell cost in NWC we use position of top-left in matrix.
6.	Travelling salesmen problem and crew Assignment are its extensions.	6.	Trans shipment problem is its extension.

5.3 QUEUING THEORY

Q14. What do you understand by a Queue?

(OR)

Define queuing theory.

Ans : **(Dec-19, July-19, Dec.18)**

In everyday life, it is seen that a number of people arrive at a cinema ticket window. If the people arrive "too frequently" they will have to wait for getting their tickets or sometimes do without it. Under such circumstances, the only alternative is to form a queue, called the waiting line, in order to maintain a proper discipline. Occasionally, it also happens that the person issuing tickets will have to wait, (i.e. remains idle), until additional people arrive. Here the arriving people are called the customers and the person issuing the tickets is called a server.

Another example is represented by letters arriving at a typist's desk. Again, the letters represent the customers and the typist represents the server. A third example is illustrated by a machine breakdown situation. A broken machine represents a customer calling for the service of a repairman. These examples show that the term customer may be interpreted in various number of ways. It is also noticed that a service may be performed either by moving the server to the customer or the customer to the server.

5.3.1 Concepts of Queue

Q15. Explain the basic elements of a queuing a system.

Ans :

The following terms are commonly used in queue models.

1. Customers

The persons or objects that require certain service are called customers.

2. Server

The person or an object or a machine that provides certain defined service is known as server.

3. Service

The activity between server and customer is called service that consumes some time.

4. Queue or Waiting Line

A systematic or a disciplined arrangement of a group of persons or objects that wait for a service is called queue or waiting line.

5. Arrival

The process of customers coming towards service facility or server to receive certain service is Arrival.

6. Mean Rate of Arrival

The average number of customers arriving per unit time is called mean rate of arrival and is denoted by 'λ'.

7. Mean Inter-arrival Time

It is the average time gap between two consecutive arrivals of customers. It is the inverse of mean arrival rate i.e.,

$$1/\lambda = \frac{Total\ arrival\ time}{Number\ of\ arrivals}$$

8. Rate of Service

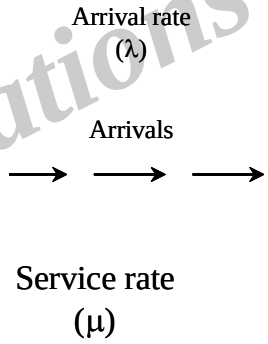
It is the average number of customers served per unit time and is denoted by μ.

9. Mean Service Time

It is the average time taken by the server to serve a customers and is equal to inverse of service rate i.e., $1/\mu$

$$= \frac{Total\ service\ time}{Number\ of\ customers\ served}$$

Suppose a queue system whose arrival rate is λ and service rate is μ.



Now, in this system any of the following three relations must occur.

(i) $\lambda > \mu$

(ii) $\lambda = \mu$

(iii) $\lambda > \mu$

(i) When $\lambda > \mu$, i.e, the rate of arrival is greater than rate of service, i.e., number of customers arriving is greater than number of customers served per unit time (time kept constant), the system results in piling up of arrived customers waiting for service and thus a queue results.

(ii) If $\lambda = \mu$, i.e., number of customers arrived is equal to customers served, there will not be any waiting, and this queue system has cent percent efficiency.

(iii) If $\lambda < \mu$, i.e. number of customers arriving is less than number of customers served per unit time. This means that server will be free, waiting for server's point of view.

Thus queue results where there is an imperfect matching between the rate of arrival and the rate of service.

Q16. Give some important applications of a queuing system.

Ans :

(a) Industrial Production Process

i) Facilities required to keep a batch of machines in economic operation. Supply of raw materials, despatch of finished products.

ii) Costly items in stock (inventory).

iii) Assembly lines.

iv) Tool room service.

vi) Storage/Dumps

vii) Computer centres.

(b) Transport

i) No. of bus terminals/bus stops.

ii) No. of siding/platforms.

iii) No.of runways/checking counters in airports.

iv) Shipping - No. of births/pilots.

(c) Communication

(i) Trunk calls
(ii) Telephones
} No.of booths/line

(d) Public Service Industry

i) Hospital Wards/Out Patients Depth. required in a Hospital.

ii) Level crossings/Tool booths required/ Ticket counters.

iii) Banks/Insurance Companies.

(e) Others

i) (Human relations) / Co-ordination - No. of subordinates to an Executive.

ii) Waiting for promotion.

iii) Waiting to die from birth (stages).

(iv) Theatres/Hours for arranging screening of pictures/wedding/meetings.

v) Waiting for ticket to see picture.

5.3.2 General Structure of a Queuing System

Q17. Describe in detail queuing structures and basic component of a queuing model.

Ans :

Queuing Structures

The general structure of a queuing system is shown in the figure below:

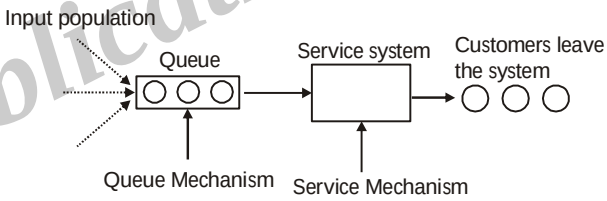


Fig. Queuing Structures

The basic process assumed by most queuing model (as depicted in the above figure) is as follows,

1. Customer requiring services are generated over time by an input source.
2. These customers enter the queuing system and join a queue.
3. At certain time, a member of the queue is selected for service by some rule called queue discipline.
4. The required service is then provided to the customer by the service mechanism.
5. The customer leaves the queuing system.

Elements

1) Input Source or Population : The input source or population is a set that contains the

probable potential customers to come out for service.

2) **Arrival Pattern :** The customers are expected to arrive at their own convenience and conditions. The patterns of arrival times often follow one of the following probability distribution.

   i) Poisson distribution (represented by M)

   ii) Exponential distribution (represented by M)

   iii) Erlang distribution (represented by E_r)

3) **Limit of Queue :** (Restricted/unrestricted queues). The limit of queue is some times restricted buy server's behaviour. If the limit is imposed by the server, the arrivals will be limited for a given period. If there is no restriction, the queue is said to be unlimited or infinite. The limited queue is denoted by N while unlimited queue by

4) **Queue Discipline :** It is the order in which the customer is selected from the queue for service. There are numerous ways in which customers in queue can be served of which some are listed below.

   (a) First In First Out (FIFO) or First Come first serve (FCFS) : It is the discipline in which the customers are served in the chronological order of their arrivals.

   Eg. Tickets at a cinema hall; sales at a grocery shop, trains on a (single line) platform etc.

   (b) Last In First Out (LIFO) or Last Come First Serve (LCFS) : If the service is made in opposite order of arrivals of customers, i.e, who ever comes last is served first and first obviously goes to last, it is called LIFO or LCFS system.

   Eg. Stack of plates: Loading and unloading a truck or go-down; office filing of papers in chronological orders; wearing socks and shoes; dressing a shirt and coat over it, packing systems etc.

   (c) Service In Random Order (SIRO) : By this rule, the customer for service is picked up at random, irrespective of their arrivals.

   Eg. Lottery system from which one is picked up, the dresses waiting in a ward robe from which one is to be chosen, food stuffs in a buffet, sales counter of commodities or vegetables etc.

   (d) Priority Service : Under this rule, the server gives priority to certain customer (s) due to some importance or prestigeous or high cost group of the customers.

   Eg. A telephone urgent call given to a customer is charged at higher price, a separate counter for cheques at a electricity bill payment counter.

   (e) Pre-emptive Priority Rule : Under this rule, highest priority is given to certain customer(s) irrespective of their arrival and costs.

   Eg., An emergency case arriving at a doctor's clinic who is attending to a regular out-patient. (The doctor will stop his service to the regular patient and immediately rushes to emergency case).

   (f) Non Pre-emptive Priority Rule : There is also a rule by priority to the special customer with the priority will not pre-emptive the current service. The service to the special customer starts immediately after the completion of current service.

   Eg. A medical representative will be given appointment immediately after the

current service to an out-patient at a doctor's clinic.

5) **Customer's Behaviour :** A customer coming out of population with an intention to receive certain service may prepared to wait till he gets service. If he waits, hoping to get the service, he is called 'patient customer' or 'positive customer' may walk out of the queue without getting service due to various reasons such as long queue in front of him or not having patience to wait etc., he is said to be an 'impatient customer' or 'negative customer' or 'pessimistic customer'. Various types of negative behaviours are defined here below :

(a) Baling: A customer who gets discouraged by seeing the length of the queue before him and thinks that he may not get service, may walk out or may not join the queue. He is said to be 'Balking'.

(b) Reneging : A customer who joins the queue and waits for some time but leaves the queue due to intolerable delay or impatient to wait any longer is said to be 'Reneging'.

(c) Jockeying : A customer who moves from one queue to another hoping to receive a more quick service is said to be 'Jockeying'.

A customer who receives service also may have negative behaviour as given below:

(d) Unsatisfied Customer : A customer who is not satisfied by the service by the quantity is said to be unsatisfied.

(e) Dissatisfied Customer : A customer who is not satisfied by the quality of service is said to be dissatisfied.

6) **Type of Service :** The service system may be in two ways as given below :

(a) Customer stationary and server moving.

Eg: (i) Arranged meal at which server brings what customer desires.

(ii) A machine waiting for repair.

(b) Server stationary and customer moving.

Eg: (i) A buffet meal where customer goes to buffet table and gets what he wants.

(ii) An aeroplane waiting for a run way for landings.

7) **Service Patterns :** The variations depend on the rate of arrival and server's behaviour. These times can be fit into one of the following probability distribution patterns.

(a) Poisson distribution (denoted by M)

(b) Exponential distribution (denoted by M)

(c) Erlang distribution (denoted by E_r)

(d) General fashion (denoted by G)

8) **Number of Servers :** A queue system and its associated costs depend on the level of service which includes both the rate of service and number of service facilities. There are two ways, to the queue problem with regard to number of service facilities.

(a) Single server system represented by 1.

(b) Multiserver system represented by S.

9) **Service Configurations :** The efficiency and capacity of a queue system can be increased by arranging the service systems in an effective way, particularly when multi-service facilities are available. Various arrangements of service facilities can be classified into following three ways.

(a) Services Configuration :

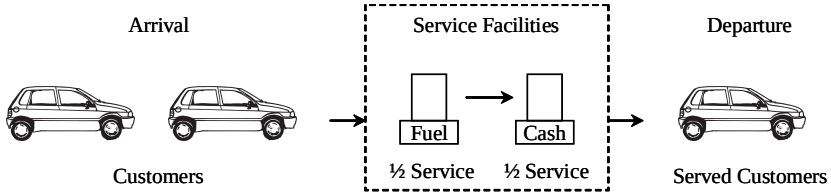


Fig. : Series Configuration

Here service is divided into certain parts served sequentially

(b) Parallel Configuration :

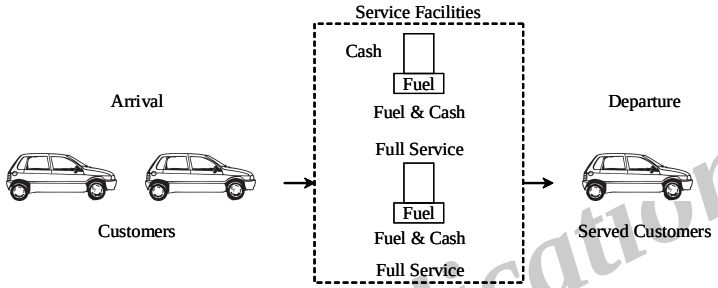


Fig. : Parallel Configuration

Here arrivals are divided into parts and separated in the different queues.

(c) Combined Configuration : This configuration is a combination of the above two configuration.

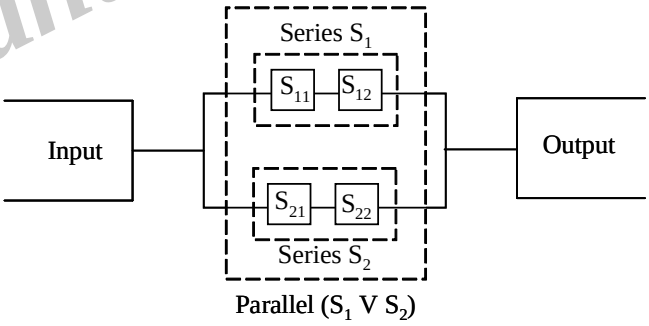


Fig. : Combination configuration

10) State of Service : The service system is influenced by service time distribution and on server's behaviour. On close observation of the changes that occur in service system, we can find three states of service viz.,

(a) Unsteady state.

(b) Transient state.

(c) Steady state.

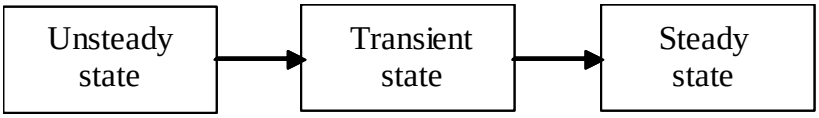


Fig.: Queue States

When the service system is just started, the server will not be able estimate how much time he has to take per customer. This state in which the server does non-uniform service is unsteady state.

From this state he slowly moves towards attaining uniformity. This consumes some time and the server during this time is said to be in transient state.

After getting enough hands on experience, the server picks up and acquires complete knowledge on the service system and takes almost same times at uniform rate to serve each customer. This state is called steady state.

11) Departure and Output : A served customer goes out of the service zone and emerges as output. This activity is often known as departure.

5.3.3 Operating Characteristics of Queues

Q18. Explain Operating Characteristics of Queue System.

Ans : **(Dec.-20)**

1. Expected number of customers in queue or size (or length) of queue (L_q): This is the average number of customers waiting for service and is denoted by L_q.

2. Expected number of customer in system or size (or length) of the system (L_s): It is the average number of customers expected to be waiting in queue and being in service. It is denoted by L_s.

3. Expected waiting time in queue (w_q): This is average time spent by a customer in queue before the commencement of the service. This is denoted by W_q.

4. Expected waiting time in the system (w_s): It is the total time spent by a customer in the system, which includes the waiting time in queue and the service time. It is represented with W_s.

$$W_s = W_q + \text{mean service time} = W_q + \frac{1}{\mu}$$

5. The server utilisation factor or fraction of busy period or traffic intensity :

It is the proportion of the time that a serve actually spends with the customers. In other words it is the probable period of server being busy. It is designated with a greek letter ρ (rho).

$$\rho = \frac{\text{Average service completion time } (1/\mu)}{\text{Averag intoer arrival time}(1/\lambda)} = \frac{\lambda}{\mu}$$

Q19. State the problems of Queuing Theory

Ans : **(Imp.)**

In a specified queueing system, the problem is to determine the following :

(a) **Probability distribution of queue length:** When the nature of probability distributions of the arrival and service patterns is given, the probability distribution of queue length can be obtained. Further, we can also estimate the probability that there is no queue.

(b) **Probability distribution of waiting time of customers:** We can find the time spent by a customer in the queue before the commencement of his service which is called his waiting time. The total time spent by him in the system is the waiting time plus service time.

(c) **The busy period distribution:** We can estimate the probability distribution of busy periods. If we suppose that the server is free initially and customer arrives, he will be served immediately. During his service time, some more customers will arrive and will be served in their turn. This process will continue in this way until no customer is left unserved and the server becomes free again. Whenever this happens, we say that a busy period has just ended. On the other hand, during idle periods no customer is present in the system. A busy period and the idle period following it together constitute a busy cycle. The study of the busy period is of great interest in cases where technical features of the server and his capacity for continuous operations must be taken into account.

Q20. Give some managerial applications of queuing models.

Ans : **(Imp.)**

Some of the managerial applications of queuing models are :

(i) Manufacturing Units

Determining the number of machines required in such a way that cost of waiting and cost of serving are leading to least total cost so that the overall manufacturing cost reduces.

(ii) Maintenance

Determining the number of repairmen required to repair the breakdown machines which arrive randomly The optimum number of repairmen will make the sum of the cost of repairmen.

(iii) Wage Incentive Plans

The efficiency to be exercised vary with machines and its types. The probabilities computed from queuing theory help in determining the base rate for such operations.

(iv) Harbour

Determination of proper number of docks to be constructed (for trucks or ships) in such a way that sum of the dock cost and demurrage costs are minimized.

Exercise Problems

1. Find the assignment that minimises total machining time. The data is

Tasks	A	B	C	D
M/CI	4	9	8	5
M/C2	5	4	3	6
M/C3	7	8	6	12
M/C4	10	9	6	7

[Ans : M_1 – A, M_2 – B, M_3 – C, M_4 – D, Min time = 21 units]

2. A company has six maintenance groups to repair six machines. The following table gives the return in rupees when the I^{th} job is assigned to the j^{th} mechanic (i, j =1, 2, 3, 4, 5, 6): How should the jobs be assigned to the mechanics so as to maximise the overall return?

Machine / Mechanic	I	II	III	IV	V	VI
1	9	22	58	11	19	27
2	43	78	72	50	63	48
3	41	28	91	37	45	33
4	74	42	27	49	39	32
5	36	U	57	22	25	18
6	13	56	53	31	17	28

[Ans: 1– VI, 2 – V, 3 – III, 4 – 1, 5 – IV and 6 – II; Maximum return = Rs. 333]

3. A department has four subordinates and four tasks to be performed. The sub-ordinates differ in efficiency and the tasks differ in their intrinsic difficulties. The estimate of man-hours, each man would take to perform the task is given below :

Task / Sub ordinate	I	II	III	IV
1	18	26	17	11
2	13	28	14	26
3	38	19	18	15
4	19	26	24	10

How should the tasks be allotted to men to optimise the total man-hours?

[Ans : 1 – III, 2 – 1,3 – II, 4 – IV, Man hrs = 59]

4. Solve the following assignment model. The assignment costs in rupees are given below :

	P	Q	R	S	T
A	3	9	2	3	7
B	6	1	5	6	6
C	9	4	7	10	3
D	2	5	4	2	1
E	9	6	2	4	6

[Ans : A – P, B – Q C – T, D – S, E – R (or) A – S, B – Q, C – T, D – P, E – R Min cost = Rs 11]

5. Solve the following unbalanced assignment problem of minimising total time for doing all the jobs.

		Jobs				
		1	2	3	4	5
Operator	1	6	2	5	2	6
	2	2	5	8	7	7
	3	7	8	6	9	8
	4	6	2	3	4	5
	5	9	3	8	9	7
	6	4	7	4	6	8

[Ans : 1 → 4, 2 → 1, 3 → dummy i.e., 6, 4 → 5, 5 → 2, 6 → 3 Min time = 16 units]

Short Question & Answers

1. Least Cost Method (LCM)

Ans :

Least cost method is also known as lowest cost entry method or matrix minima method. To achieve the objective of minimum transportation cost, this method consider those routes (or cells) with least unit transportation cost to transport the goods.

Steps

The steps of LCM are as follows,

Step-1

The cell with the smallest unit cost of transportation is chosen and as many units as possible are allocated to that cell. If there is a tie in the least cost, the cell where maximum allocation is possible is chosen.

Step-2

Adjust the supply and demand for the allocation made and eliminate (strike out) the row or column in which either supply or demand is exhausted. If both are exhausted simultaneously, both must be eliminated simultaneously.

Step-3

Repeat steps (1) and (2) with the next smallest unit cost of transportation among the remaining cells (uncrossed-out cells).

Step-4

Continue the procedure until the entire available supply at various sources and entire demand at various destinations are satisfied.

2. Explain Operating Characteristics of Queue System.

Ans :

1. **Expected number of customers in queue or size (or length) of queue (L_q):** This is the average number of customers waiting for service and is denoted by L_q.
2. **Expected number of customer in system or size (or length) of the system (L_s):** It is the average number of customers expected to be waiting in queue and being in service. It is denoted by L_s.
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$$W_s = W_q + \text{mean service time} = W_q + \frac{1}{\mu}$$

5. The server utilisation factor or fraction of busy period or traffic intensity :

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$$\rho = \frac{\text{Average service completion time } (1/\mu)}{\text{Averag intoer arrival time}(1/\lambda)} = \frac{\lambda}{\mu}$$

3. Define queuing theory.

Ans :

In everyday life, it is seen that a number of people arrive at a cinema ticket window. If the people arrive "too frequently" they will have to wait for getting their tickets or sometimes do without it. Under such circumstances, the only alternative is to form a queue, called the waiting line, in order to maintain a proper discipline. Occasionally, it also happens that the person issuing tickets will have to wait, (i.e. remains idle), until additional people arrive. Here the arriving people are called the customers and the person issuing the tickets is called a server.

Another example is represented by letters arriving at a typist's desk. Again, the letters represent the customers and the typist represents the server. A third example is illustrated by a machine breakdown situation. A broken machine represents a customer calling for the service of a repairman. These examples show that the term customer may be interpreted in various number of ways. It is also noticed that a service may be performed either by moving the server to the customer or the customer to the server.

4. Write a brief note on unbalanced assignment problem (AP).

Ans :

An assignment problem is said to be unbalanced if the number of rows is not equal to the number of columns. Number of rows n(r) = Number of columns n(c) balanced AP. Number of rows n(4) $\neq$ number of column n(c) unbalanced AP.

The AP is balanced if the AP matrix is a square and unbalanced if it is not a square matrix.

In unbalanced AP, we notice that either number of jobs are greater or lesser than number of men or machine. In such case, a dummy row/column will be created with zero costs to each cell. Observe the following example to convert unbalanced AP to balanced AP.

	M_1	M_2	M_3
J_1	x_{11}	x_{12}	x_{13}
J_2	x_{21}	x_{22}	x_{23}
J_4	x_{31}	x_{32}	x_{33}
J_5	x_{41}	x_{42}	x_{43}

Unbalanced :
Machines (3) ≠ jobs (4)

	M_1	M_2	M_3	Dummy
J_1	x_{11}	x_{12}	x_{13}	0
J_2	x_{21}	x_{22}	x_{23}	0
J_4	x_{31}	x_{32}	x_{33}	0
J_5	x_{41}	x_{42}	x_{43}	0

Balanced :
Machines (4) = jobs (4) here D is Dummy machine.

Similarly, if jobs are less, we create a dummy row with zero costs.

5. What is a transportation problem ?

Ans :

Meaning

Transportation problem is another case of application to linear programming problems, where some physical distribution (transportation) of resources is to be made from one place to another to meet certain set of requirements with in the given availability. The places from where the resources are to be transferred are referred to as sources or origins. These Sources (or) origins will have the availability or capacity (or) supply of resources. The other side of this transportation i.e. to where the resources are transported are called sinks (or) destinations such as market centres, godowns etc. These will have certain requirements or demand.

For example, a tyre manufacturing concern has m factories located in m different cities. The total supply potential of manufactured product is absorbed by n retail dealers in n different cities of the country. Then, transportation problem is to determine the transportation schedule that minimizes the total cost of transporting tyres from various factory locations to various retail dealers.

6. What is Vogels Approximation Method (VAM)?

Ans :

VAM or Vogel's Approximation Method is also known as penalty or regret method. It is basically a heuristic method. Allocation is done on the basis of opportunity cost (penalty) that would have incurred if allocation in certain cells with minimum costs were missed.

The steps involved in this method for finding the initial solution are as follows.

Step 1

Find the penalty cost, namely the difference between the smallest and next smallest costs in each row and column.

Step 2

Among the penalties as found in step (1) choose the maximum penalty. If this maximum penalty is more than one (i.e if there is a tie) choose any one arbitrarily.

Step 3

In the selected row or column as by step (2) find out the cell having the least cost. Allocate to this cell as much as possible depending on the capacity and requirements.

Step 4

Delete the row or column which is fully exhausted. Again compute the column and row penalties for the reduced transportation table and then go to step (2) Repeat the procedure until all the rim requirements are satisfied.

Note If the column is exhausted, then there is a change in row penalty and vice versa.

7. Define Assignment Problem.

Ans :

The name 'Assignment Problem' originates from the classical problems where the objective is to assign a number of origins (jobs) to the equal number of destinations (persons) at a minimum cost (or maximum profit). To examine the nature of assignment problem, suppose there are n jobs to be performed

and n persons are available for doing these jobs. Assume that each person can do each job at a time, though with varying degree of efficiency. Let C_{ij} be the cost (payment) if the ith person is assigned the jth job, the problem is to find an assignment (which job should be assigned to which person) so that the total cost for performing all jobs is minimum. Problems of this kind are known as assignment problems.

Jobs

Persons		I	2	...	j	...	n
	1	C_{11}	C_{12}	...	C_{ij}	...	C_{1n}
	2	C_{2I}	C_{22}	...	C_{2j}	...	C_{2n}
	:	:	:				:
	i	C_{i1}	C_{i2}	...	C_{ij}	...	C_{in}
	:	:	:		:		:
	n	C_{n1}	C_{n2}	...	C_{nj}	...	C_{nn}

Table.: Assigment Problem

Further, such types of problems may consist of assigning men to offices, classes to rooms, drivers trucks, trucks to delivery routes (or) problems toxesearch teams etc.. The assignment problem can be stated the form of n × n cost-matrix $[c_{ij}]$ of real number.

8. Jockeying

Ans :

A customer who moves from one queue to another hoping to receive a more quick service is said to be 'Jockeying'.

A customer who receives service also may have negative behaviour as given below:

9. Service Patterns

Ans :

The variations depend on the rate of arrival and server's behaviour. These times can be fit into one of the following probability distribution patterns.

(a) Poisson distribution (denoted by M)

(b) Exponential distribution (denoted by M)

(c) Erlang distribution (denoted by E_r)

(d) General fashion (denoted by G)

10. Problems of Queuing Theory

Ans :

In a specified queueing system, the problem is to determine the following :

(a) Probability distribution of queue length: When the nature of probability distributions of the arrival and service patterns is given, the probability distribution of queue length can be obtained. Further, we can also estimate the probability that there is no queue.

(b) Probability distribution of waiting time of customers: We can find the time spent by a customer in the queue before the commencement of his service which is called his waiting time. The total time spent by him in the system is the waiting time plus service time.

(c) The busy period distribution: We can estimate the probability distribution of busy periods. If we suppose that the server is free initially and customer arrives, he will be served immediately. During his service time, some more customers will arrive and will be served in their turn. This process will continue in this way until no customer is left unserved and the server becomes free again. Whenever this happens, we say that a busy period has just ended. On the other hand, during idle periods no customer is present in the system. A busy period and the idle period following it together constitute a busy cycle. The study of the busy period is of great interest in cases where technical features of the server and his capacity for continuous operations must be taken into account.

Choose the Correct Answers

1. Which of the following method may yield same IBFS for both minimisation and maximisation of same data. [c]

   (a) Vogel's approximation (b) least cost entry method

   (c) north west comer rule (d) row minima method

2. In which of the following cases degeneracy may not appear [c]

   (a) partial sura of supplies is equal to partial sum of demands

   (b) both row and column are satisfied in same step in Vogel's approximation

   (c) same least cost for more than one cells

   (d) no. of allocated cells is less than rows + columns - 1

3. Which of the following methods uses penalties to find IBFS [b]

   (a) north west corner method (b) Vogel's approximation method

   (c) least cost entry method (d) column minima method

4. Which of the following method to find IBFS of transportation problem is independent of costs / profit of transportation matrix [a]

   (a) north west corner rule (b) Vogel's approximation

   (c) matrix minima method (d) row minima method

5. In a maximisation case of T.P, we convert it to minimisation case by [b]

   (a) adding every cell value to highest among them

   (b) subtracting every cell value from highest among them

   (c) dividing cell value with lowest among them

   (d) subtracting least value of each row in the corresponding row.

6. To find IBFS in maximising T.P, which erf the following is wrong [b]

   (a) allocation is made at cell with highest value in LCEM

   (b) allocation is made by using highest penalty at the cell with least cost

   (c) all cells are multiplied by (-1) before allocating

   (d) all values are subtracted from highest value among all cells.

7. If total supply > total demand, then add [b]

(a) dummy supply centre

(b) dummy demand centre

(c) dummy supply and dummy demand centre

(d) difference at any demand centre

8. Degeneracy is observed if [d]

(a) a row and column are simultaneously filled-up in north west corner method.

(b) no. of allocated cells phis one is less than sum of no. of rows and no. of columns in a T.P.

(c) minimum ratio is found equal for two or more basic variables in simplex

(d) any of the above

9. Which of the following is false in the case of loop drawn while optimising a T.P. [d]

(a) every loop must have even number of comers

(b) a loop must have at least four comers

(c) closed loop may or may not be a square/rectangle

(d) the loop lines need not be horizontal and vertical lines

10. If number of rows exceeds the number of columns by 2, then we add [d]

(a) a dummy row (b) 2 dummy rows

(c) a dummy column (d) 2 dummy columns

11. The cost of assignment in a dummy cell is [b]

(a) unity (b) zero

(c) ∞ (d) negative

12. An opportunity cost table of AP is prepared by [c]

(a) subtracting every element from highest among them

(b) multiplying by (-!) in all cells

(c) subtracting least of each row in corresponding row and then least of every column in corresponding column

(d) transposing the matrix

13. While revising the opportunity cost table of AP, we put the lines across [c]

(a) marked rows and unmarked columns

(b) marked rows and marked columns

(c) unmarked rows and marked columns

(d) unmarked rows and unmarked columns

14. In AP, we get multiple optimal solutions if [a]

(a) a loop can be constructed with zeros having assignment at alternate comers

(b) minimum number of lines is greater than the order

(c) minimum number of lines is equal to the order

(d) minimum number of lines is less than the order

15. A matrix of travelling salesman problem contains [d]

(a) no figures along at least one row

(b) no figures along at least one column

(c) no figures along the diagonals

(d) no figures along the principal diagonal

16. An opportunity cost matrix of AP should have [c]

(a) at least one zero in each row

(b) at least one zero in each column

(c) both (a) & (b) of the above

(d) no zeros in at least one column or row

17. A customer buying tickets in a black market at a cinema hall is said to be [c]

(a) balker (b) reneger

(c) jockeyer (d) dissatisfied

18. An expediting in production shop in example for _____ queue discipline [d]

(a) FIFO (b) UFO

(c) SIRO (d) pre-emptive

19. The dead bodies coming to a grave yard is an example of [b]

(a) pure death process (b) pure birth process

(c) birth and death process (d) not a queue process

20. In (M/M/S): (N/FIFO), which of the following is wrongly stated [c]

(a) poisson arrival (b) exponential service

(c) single server (d) limited service

21. Which of the following is not considered as the negative behaviour of customer according to queue disciplines [d]

(a) reneging (b) jockeying

(c) balking (d) boarding

Fill in the Blanks

1. In NWCM, the allocation is independent of _____ of the transportation.
2. The top-left cell of the TP is necessarily allocated in _____ method
3. The total supply must be equal to total demand. This condition is called _____ .
4. If partial sum of supply is equal to partial sum of demands then _____ may appear
5. Penalties are used in _____ method of finding IBFS in TP
6. A TP is said to be balanced if _____ .
7. A TP is said to be non-degenerate if _____ .
8. The criterion used in VAM (to fmd IBFS) is _____ .
9. The costs of dummy cells are taken as _____ .
10. If an assignment problem is square it is called _____ .
11. We can convert a maximisation AP to minimisation AP by multiplying every cell with _____ .
12. Costs of dummy row/column are usually taken as _____ .
13. We put lines across _____ rows and _____ column while revising opportunity cost table of AP
14. The optimisation is said to be reached in AP if minimum number of lines covering all zeros is equal to _____ .
15. If a rectangular loop constructed by all zeros with alternative assignment on the comers of the loop can be obtained, the AP will have _____ .
16. If an AP has condition that the solution must be cyclic, then the AP is said to be _____ .
17. The optimal solution of AP of *nxn* order should at least get _____ minimum number of lines connecting all zeros in the opportunity matrix
18. In a restricted AP with elements x_{ij}, we use 'M' as penalty with a condition that _____ .
19. While revising the opportunity cost matrix of AP, we identify least among unlined numbers and _____ to unlined numbers and _____ to double lined (intersecting) numbers.
20. Customers losing patience out of inordinate delay in service walk out of queue system, are said to be _____ .
21. Pre paid taxi at an airport follow _____ queue discipline
22. The steady state can exist in queue system if λ _____ μ
23. The storage or memory of files in a computer (RAM) in accordance with _____ type of queue discipline.
24. The unit of utilization factor is _____ .
25. The cost of waiting per unit time _____ with increase of service level.

ANSWERS

1. cost/profit
2. North west comer
3. rim condition
4. degeneracy
5. Vogel's approximation
6. Total supply = total demand
7. $n(C_{ij}) = n(r) + n(c) - 1$
8. Penalty
9. Zero
10. Balanced AP
11. – 1
12. Aeros
13. Unmarked, marked
14. No. of rows or columns or order of matrix
15. Alternate or multiple optimal solution
16. Travelling salesman problem
17. n
18. $M \pm x_{ij} = M$
19. Subtract, add
20. Reneging
21. FCFS (or) FIFO
22. < (less than)
23. SIRO
24. Erlang
25. Decreases

FACULTY OF MANAGEMENT

BBA V - Semester (CBCS) Examination

November / December - 2020

MANAGEMENT SCIENCE

Time : 2 Hours] [Max. Marks : 80

PART - A (4 × 5 = 20 Marks)

Note : Answer any four questions.

ANSWERS

1. What is process design ? **(Unit - I, SQA.1)**
2. Plant layout **(Unit - II, SQA.1)**
3. What is stores ledger ? **(Out of Syllabus)**
4. ABC Analysis. **(Unit - III, SQA.1)**
5. Work Study. **(Unit - II, SQA.2)**
6. Explain characteristics of Queues. **(Unit - V, SQA.2)**
7. What is Bin Card ? **(Out of Syllabus)**
8. Explain LCM **(Unit - V, SQA.1)**

PART - B (4 × 15 = 60 Marks)

Note : Answer any four questions.

9. Briefly explain various stages of product life cycle. **(Unit - I, Q.No.22)**
10. What do you mean by production planning and control ? Explain the functions of production planning **(Unit - I, Q.No.14,19)**
11. Five men are available to do different jobs. The time that each person takes to do the job is given in the following table.

	Jobs				
Men	1	2	3	4	5
A	2	8	2	8	1
B	5	6	8	5	1
C	4	5	4	3	1
D	4	2	6	3	1
E	5	9	7	5	1

Find the assignment of men to jobs that will minimize the total time taken.

(Unit - V, Prob.11)

12. Explain the concept and various techniques of method analysis. **(Unit - II, Q.No.27)**

13. What do you mean by inventory control ? Explain various inventory control techniques in brief. **(Unit - III, Q.No.24)**

14. What is stores management ? Explain the functions of stores management. **(Unit - III, Q.No.9)**

15. Explain the LPP by graphical method. **(Unit - IV, Q.No.14)**

16. Explain the managerial application and limitations of operations research. **(Unit - IV, Q.No.5,6)**

17. Distinguish between a transportation problem and an assignment problem. **(Unit - V, Q.No.13)**

18. An auto company has three plants A, B and C and two major distribution centers in X and Y. The capacities of the three plants during the next quarter are 1000, 2300 and 1400 cars. The transportation costs (which depend on the mileage, transport company etc) between the plants and the distribution centers is as follows :

Plant Name	Distr. Center X	Distr. Center Y
Plant A	80	215
Plant B	100	108
Plant C	102	68

Which plant should supply how many cars to which outlet so that the total cost is minimum? **(Unit - IV, Prob.12)**

FACULTY OF MANAGEMENT

BBA V - Semester (CBCS) Examination

November / December - 2019

MANAGEMENT SCIENCE

Time : 3 Hours] [Max. Marks : 80

Note : Answer all the questions

PART - A (5 × 4 = 20 Marks)

[Short Answer Type]

ANSWERS

1. Answer any five of the following in not exceeding 20 lines.

(a) Process Life Cycle **(Unit - I, SQA.3)**

(b) What do you mean by break down ? **(Out of Syllabus)**

(c) Plant Layout **(Unit - II, SQA.1)**

(d) VED Analysis **(Unit - III, SQA.2)**

(e) Material Control **(Unit - III, SQA.6)**

(f) EOQ **(Unit - III, SQA.3)**

(g) Queuing Theory **(Unit - V, SQA.3)**

(h) What is LPP ? **(Unit - IV, SQA.1)**

PART - B (5 × 12 = 60 Marks)

[Essay Answer Type]

Note : Answer all the questions using the internal choice.

2. (a) Distinguish between product life cycle and process life cycle. **(Unit - I, Q.No.24)**

OR

(b) Briefly explain the functions of production planning and control. **(Unit - I, Q.No.19)**

3. (a) What is sequencing of operations in jobs ? Explain the same with one and two facilities. **(Unit - II, Q.No.18,20,21)**

OR

(b) Explain the procedure for classification and codification of materials. **(Unit - III, Q.No.13,15)**

4. (a) What do you mean by simplification and standardization of materials ? **(Unit - III, Q.No.17,18)**

OR

(b) Explain the method of determining the EOQ with a single price breaks. **(Unit - III, Q.No.23)**

5. (a) Explain how a two person zero-sum game can be solved by linear programming. **(Unit - IV, Q.No.12)**

OR

(b) Formulate as Assignment problem as a linear programming problem. Why do you need to have a separate technique to solve this problem rather than using simplex technique ? **(Unit - V, Q.No.8)**

6. (a) Explain briefly with example North - West corner rule for transportation problem. **(Unit - V, Q.No.3)**

OR

(b) Find initial basic feasible solution using Least cost Method (LCM) for the following table.

	D_1	D_2	D_3	D_4
P_1	2	5	9	6
P_2	1	0	6	1
P_3	5	7	12	9

(Incomplete Problem)

FACULTY OF MANAGEMENT

B.B.A V - Semester (CBCS) Examination

June / July - 2019

MANAGEMENT SCIENCE

Time : 3 Hours] [Max. Marks : 80

PART - A (5 × 4 = 20 Marks)

[Short Answer Type]

ANSWERS

Answer any five of the following questions :

1. LPP **(Unit - IV, SQA.1)**
2. ABC Analysis **(Unit - III, SQA.1)**
3. Ordering Cost **(Unit - III, SQA.3)**
4. Plant location **(Unit - II, SQA.3)**
5. Decision making **(Unit - III, SQA.13)**
6. Product life cycle **(Unit - I, SQA.2)**
7. Unbalanced AP **(Unit - V, SQA.4)**
8. Queuing theory **(Unit - V, SQA.3)**

PART - B (5 × 12 = 60 Marks)

[Essay Answer Type]

Note : Answer all the questions

9. (a) Explain in brief the objectives of production management. **(Unit - I, Q.No.2)**

OR

(b) Explain the framework of managing operations. **(Unit - I, Q.No.3)**

10. (a) Explain the principal assumptions made while dealing with sequencing problems. **(Unit - II, Q.No.19)**

OR

(b) An Industrial Operation consists of the following observed times along with their performance ratings.

Element	A	B	C	D	E	F
Observed Time (Minutes)	0.20	0.10	0.50	0.12	0.18	0.25
Performance rating %	80	85	90	75	85	90

Assuming rest and personal allowance as 15% and contingency allowance as 4% of the basic time. Calculate standard time per piece **(Unit - II, Prob.9)**

11. (a) Explain :

(i) Bin Card **(Out of Syllabus)**

(ii) Two - Bin **(Out of Syllabus)**

(iii) Stores ledger **(Out of Syllabus)**

OR

(b) A factory uses annually 24,000 units of raw material which cost Rs. 125 per unit placing each order costs Rs. 25 and carrying cost is 6% per year of the average inventory :

(i) Find out the economic order quantity

(ii) How many orders are to be placed in a year ? **(Unit - III, Prob.6)**

12. (a) Explain mathematical model and formulation of LPP. **(Unit - IV, Q.No.10,11)**

OR

(b) Explain managerial applications and limitations of Operation Research. **(Unit - IV, Q.No.5,6)**

13. (a) A department has five employees with five jobs to be performed. The time (in hours) each man will take to perform each job is given in the effectiveness material.

		Employees				
		I	II	III	IV	V
Jobs	A	10	5	13	15	16
	B	3	9	18	13	6
	C	10	7	2	2	2
	D	7	11	9	7	12
	E	7	9	10	4	12

How should the jobs be allocated, one per employee, so as to minimize the total man hours? **(Unit - V, Problem.10)**

OR

(b) Enumerate the methods for finding initial solution for transportation problem. **(Unit - V, Q.No.3,4,5)**

FACULTY OF MANAGEMENT

B.B.A. V - Semester (CBCS) Examination

November / December - 2018

MANAGEMENT SCIENCE

Time : 3 Hours] [Max. Marks : 80

PART - A (5 × 4 = 20 Marks)
(Short Answer Type)

ANSWERS

Note : *Answer any* ***FIVE*** *of the following questions.*

1. Elapsed Time **(Unit - II, SQA.4)**
2. VED Analysis **(Unit - III, SQA.2)**
3. Queuing Theory **(Unit - V, SQA.3)**
4. LCM **(Unit - V, SQA.1)**
5. EOQ **(Unit - III, SQA.3)**
6. Plant layout **(Unit - II, SQA.1)**
7. Work Study **(Unit - III, SQA.2)**
8. Job Shop **(Unit - I, SQA.4)**

PART - B (5 × 12 = 60 Marks)
(Essay Answer Type)

Note : *Answer* ***ALL*** *the questions.*

9. (a) Explain the product life cycle. **(Unit - I, Q.No.22)**

OR

(b) Explain in brief the objectives of production management. **(Unit - I, Q.No.2)**

10. (a) Five jobs have to be processed on three machines X, Y,Z in the order X, Y and Z processing times are given below :

	Processing times (Minutes)		
Jobs	X	Y	Z
1	9	6	5
2	10	7	10
3	7	4	8
4	8	3	7
5	12	5	4

Determine the sequence that will minimize the elapsed time or cycle time. Find the idle time in each of the machines X, Y and Z. **(Unit - II, Prob.8)**

(b) Explain the concept and various techniques of methods analysis. **(Unit - II, Q.No.27)**

11. (a) A factory uses annually 24,000 units of raw material which cost Rs. 125 per unit placing each order costs Rs. 25 and carrying cost is 6% per year of the average inventory.

i) Find out the EOQ

ii) How many orders are to be placed in a year ? **(Unit - III, Prob.5)**

OR

(b) Discuss the ABC approach of Inventory Control system. What is the procedure followed in conducting ABC analysis. **(Unit - III, Q.No.25)**

12. (a) Explain managerial applications and limitations of operation research. **(Unit - IV, Q.No.5,6)**

OR

(b) Explain about the solution by graphical methods. **(Unit - IV, Q.No.14)**

13. (a) Explain the various types of converting maximization AP in to minimization AP. **(Unit - V, Q.No.9)**

(b) The Amulya Milk Company has three plants located throughout a state with production capacity 50, 75 and 25 gallons. Each day firm must furnish its four retail shops R_1, R_2, R_3 and R_4 with at least 20, 20,50 and 60 gallons respectively.

Plant	Retail Shop				Supply
	R_1	R_2	R_3	R_4	
P_1	3	5	7	6	50
P_2	2	5	8	2	75
P_3	3	6	9	2	25
Demand	20	20	50	60	

The economic problem is to distribute the available product to different retail shops in such a way so that the total transportation cost minimum. **(Unit - V, Prob.6)**

FACULTY OF MANAGEMENT

BBA IV - Semester (CBCS) Examination

MODEL PAPER - I

MANAGEMENT SCIENCE

Time : 3 Hours] [Max. Marks : 80

Note : Answer all the questions

PART - A (5 × 4 = 20 Marks)

[Short Answer Type]

ANSWERS

1. Answer any five of the following in not exceeding 20 lines.

(a) Define process design. **(Unit - I, SQA.1)**

(b) Objectives of PPC. **(Unit - I, SQA.7)**

(c) Plant layout **(Unit - II, SQA.1)**

(d) Predetermined Motion Time System (PMTS) **(Unit - II, SQA.12)**

(e) Economic Order Quantity. **(Unit - III, SQA.3)**

(f) Operation Research. **(Unit - IV, SQA.2)**

(g) Least Cost Method (LCM) **(Unit - V, SQA.1)**

(h) What is a transportation problem ? **(Unit - V, SQA.5)**

PART - B (5 × 12 = 60 Marks)

[Essay Answer Type]

Note : Answer all the questions using the internal choice.

2. (a) What are the objectives of production, planning and control ? **(Unit - I, Q.No.16)**

OR

(b) Discuss in detail about process life cycle. **(Unit - I, Q.No.23)**

3. (a) What are the factors influencing selection plant location ? **(Unit - II, Q.No.8)**

OR

(b) An industrial operation consists of the following observed times along with their performance rating.

Element	A	B	C	D	E	F
Observed Time (minutes)	0.20	0.10	0.50	0.12	0.18	0.25
Performance rating %	80	85	90	75	85	90

Assuming rest and personal allowance as 15% and contingency allowance as 4% of the basic time. Calculate standard time per piece. **(Unit - II, Prob.9)**

4. (a) Explain briefly about ABC Analysis. **(Unit - III, Q.No.25)**

OR

(b) Alpha industry estimates that it will sell 12,000 units of its product for the forthcoming year. The ordering cost is ` 100 per order and the carrying cost per unit per year is 20 per cent of the purchase price per unit. The purchase price per unit is ` 50. Find

(a) Economic order quantity (EOQ)

(b) No. of orders per year

(c) Time between successive orders **(Unit - III, Prob.4)**

5. (a) What are the advantages and limiations of linear programming ? **(Unit - IV, Q.No.9)**

OR

(b) Sainath and Co manufactures two brands of products namely Shivnath and Harinath. Both these models have to undergo the operations on three machines lathe, milling and grinding. Each unit of Shivnath gives a profit of Rs. 45 and requires 2 hours on lathe, 3 hours on milling and 1 hour on grinding. Each unit of Harinath can give a profit of Rs. 70 and requires 3, 5, and 4 hours on lathe, milling and grinding respectively. Due to prior commitment, the use of lathe hours are restricted to a maximum of 70 hours in a week. The operators to operate milling machines are hired for 110 hours / week. Due to scarce availability of skilled man power for grinding machine, the grinding hours are limited to 100 hours/week. Formulate the data into on LPP. **(Unit - IV, Prob.1)**

6. (a) What are the different methods of finding initial feasible solution. Discuss briefly about North West Corner method. **(Unit - V, Q.No.3)**

OR

(b) Solve the following assignment problem by Hungarian assignment method.

Time (in minutes)			
Worker	Job 1	Job 2	Job 3
A	4	2	7
B	8	5	3
C	4	5	6

(Unit - V, Prob.1)

FACULTY OF MANAGEMENT

BBA IV - Semester (CBCS) Examination

MODEL PAPER - II

MANAGEMENT SCIENCE

Time : 3 Hours] [Max. Marks : 80

Note : Answer all the questions

PART - A (5 × 4 = 20 Marks)

[Short Answer Type]

ANSWERS

1. Answer any five of the following in not exceeding 20 lines.

(a) Explain the limitations of PPC. **(Unit - I, SQA.9)**

(b) What are the principles of PPC ? **(Unit - I, SQA.8)**

(c) Work Study **(Unit - II, SQA.2)**

(d) Fixed position Layout. **(Unit - II, SQA.7)**

(e) VED Analysis. **(Unit - III, SQA.2)**

(f) Discuss Mathematical Model of LPP. **(Unit - IV, SQA.6)**

(g) Define queuing theory. **(Unit - V, SQA.3)**

(h) Define Assignment Problem. **(Unit - V, SQA.7)**

PART - B (5 × 12 = 60 Marks)

[Essay Answer Type]

Note : Answer all the questions using the internal choice.

2. (a) What are the functions of PPC ? **(Unit - I, Q.No.19)**

OR

(b) State the relationship between product life cycle and process life cycle. **(Unit - I, Q.No.24)**

3. (a) What is Process Layout ? Explain the functions, advantages and disadvantages of process layout. **(Unit - II, Q.No.13)**

OR

(b) A group of six jobs is to be processed through a two machine flow shop. The first operation involves cleaning and the second involves painting. Determine a sequence that will minimize the total completion time for this group of jobs. Also compute the time.

Job	A	B	C	D	E	F
Cleaning (M_1)	5	4	8	2	6	12
Cleaning (M_2)	5	3	9	7	8	15

(Unit - II, Prob.4)

4. (a) Describe the various methods of Vendor Rating. **(Unit - III, Q.No.7)**

OR

(b) From the following data draw an ABC analysis graph after classifying A, B & C class items.

Item	Unit price	Annual Consumption (units)
1	200.0	3,000
2	2.0	60,000
3	5000.0	20
4	12.5	200
5	9.0	350
6	25.0	6,000
7	1000.0	40
8	70.0	300

(Unit - III, Prob.7)

5. (a) Explain how a two person zero sum game can be solved by linear programming. **(Unit - IV, Q.No.12)**

OR

(b) Solve the following LPP by graphical method.

Minimize $Z = 20X_1 + 10X_2$

Subject ot $X_1 + 2X_2 \leq 40$

$3X_1 + X_2 \geq 30$

$4X_1 + 3X_2 \geq 60$

$X_1, X_2 \geq 0.$

(Unit - IV, Prob.6)

6. (a) What is Vogels Approximation Method (VAM)? Explain the steps to get an initial basic feasible solution by Vogels Approximation Method. **(Unit - V, Q.No.5)**

OR

(b) Consider the following transportation problem

	Destination				
Source	D_1	D_2	D_3	D_4	Total
O_1	1	2	1	4	30
O_2	3	3	2	1	50
O_3	4	2	5	9	20
Total	20	40	30	10	100

Determine the initial feasible solution **(Unit - V, Prob.2)**

FACULTY OF MANAGEMENT

BBA IV - Semester (CBCS) Examination

MODEL PAPER - III

MANAGEMENT SCIENCE

Time : 3 Hours] [Max. Marks : 80

Note : Answer all the questions

PART - A (5 × 4 = 20 Marks)

[Short Answer Type]

ANSWERS

1. Answer any five of the following in not exceeding 20 lines.

(a) Continuous Process. **(Unit - I, SQA.12)**

(b) Define Job Process. **(Unit - I, SQA.4)**

(c) Plant Location **(Unit - II, SQA.3)**

(d) Combined Layout. **(Unit - II, SQA.8)**

(e) FSND Analysis. **(Unit - III, SQA.11)**

(f) What is Linear Programming Problem ? **(Unit - IV, SQA.1)**

(g) Major assumptions of LPP. **(Unit - V, SQA.7)**

(h) Write a brief note on unbalanced assignment problem (AP). **(Unit - V, SQA.4)**

PART - B (5 × 12 = 60 Marks)

[Essay Answer Type]

Note : Answer all the questions using the internal choice.

2. (a) Explain briefly about product life cycle. **(Unit - I, Q.No.22)**

OR

(b) Explain in brief the objectives of production management. **(Unit - I, Q.No.2)**

3. (a) What are the various types of charts used in method study? **(Unit - II, Q.No.27)**

OR

(b) Find the sequence that minimizes total machining time to complete the following data.

Job	A	B	C	D	E	F
M I	4	9	8	5	10	9
M II	5	4	3	6	2	5
M III	7	8	6	12	6	7

(Unit - II, Prob.7)

4. (a) Explain the concept of simplification. **(Unit - III, Q.No.17)**

OR

(b) What are the various techniques of Inventory Control? **(Unit - III, Prob.24)**

5. (a) What do you mean by Graphical Method of LPP? State the characteristics of Graphical Method. **(Unit - IV, Q.No.14)**

OR

(b) "Operations Research replace management by personality". Discuss. **(Unit - IV, Prob.5)**

6. (a) Describe in detail queuing structures and basic component of a queuing model. **(Unit - V, Q.No.17)**

OR

(b) A company has factories at F1, F2 and F3 which supply warehouses at W1, W2 and W3. Weekly factory capacities are 200, 160 and 90 units respectively. Weekly warehouse requirements are 180, 120 and 150 units respectively. Unit shipping costs (in rupees) are as follows,

	Warehouse			
Factory	W1	W2	W3	Supply
F1	16	20	12	200
F2	14	8	18	160
F3	26	24	16	90
Demand	180	120	150	450

Determine the optimum distribution for this company to minimize shipping costs.

(Unit - V, Prob.4)