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For

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Industrial Engineering

By

Gagan Chaudhary



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Production Planning and control: Forecasting techniques – causal and time series models, moving average, exponential smoothing, trend and seasonality; aggregate production planning; master production scheduling; materials requirement planning (MRP) and MRP-II; routing, scheduling and priority dispatching, concept of JIT manufacturing system. Project Management: Project network analysis, CPM, PERT and Project crashing.

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UNIT-4 : WORK SYSTEM DESIGN (4-1 A to 4-27 A)

Work System Design: Taylor's scientific management, Gilbreth's contributions; work study: method study, micro-motion study, principles of motion economy; work measurement-time study, work sampling, standard data, Predetermined motion time system (PMTS); ergonomics; job evaluation, merit rating, incentive schemes, and wage administration. Product Design and Development: Principles of product design, tolerance design; quality and cost considerations; product life cycle; standardization, simplification, diversification, value engineering and analysis, and concurrent engineering.

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SHORT QUESTIONS

(SQ-1 A to SQ-15 A)

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Subject Code: KME 503	Industrial Engineering	L T P : 3 1 0	Credits: 4
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Course Outcomes: The students will be able to		Blooms Taxonomy
CO1	Understand the concept of production system, productivity, facility and process planning in various industries	K2
CO2	Apply the various forecasting and project management techniques	K3
CO3	Apply the concept of break-even analysis, inventory control and resource utilization using queuing theory	K3
CO4	Apply principles of work study and ergonomics for design of work systems	K3
CO5	Formulate mathematical models for optimal solution of industrial problems using linear programming approach	K4

Unit-I:

Overview of Industrial Engineering: Types of production systems, concept of productivity, productivity measurement in manufacturing and service organizations, operations strategies, liability and process design.

Facility location and layout: Factors affecting facility location; principle of plant layout design, types of plant layout; computer aided layout design techniques; assembly line balancing; materials handling principles, types of material handling systems, methods of process planning, steps in process selection, production equipment and tooling selection, group technology, and flexible manufacturing.

Unit II:

Production Planning and control: Forecasting techniques – causal and time series models, moving average, exponential smoothing, trend and seasonality; aggregate production planning; master production scheduling; materials requirement planning (MRP) and MRP-II; routing, scheduling and priority dispatching, concept of JIT manufacturing system

Project Management: Project network analysis, CPM, PERT and Project crashing.

Unit III:

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Queuing Theory: Basis of Queuing theory, elements of queuing theory, Operating characteristics of a queuing system, Classification of Queuing models.

Unit IV

Work System Design: Taylor's scientific management, Gilbreths's contributions; work study: method study, micro-motion study, principles of motion economy; work measurement –time study, work

sampling, standard data, Predetermined motion time system (PMTS); ergonomics; job evaluation, merit rating, incentive schemes, and wage administration.

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Unit V:

Operational Analysis: Formulation of LPP, Graphical solution of LPP, Simplex Method, Sensitivity Analysis, degeneracy and unbound solutions. transportation and assignment models; Optimality test: the stepping stone method and MODI method, simulation.

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Overview of Industrial Engineering

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PART- 1

Types of Production Systems, Concept of Productivity, Productivity Measurement in Manufacturing and Service Organizations.

Questions-Answers**Long Answer Type and Medium Answer Type Questions**

Que 1.1. What do you mean by production ? Explain production system.

Answer**A. Production :**

1. It is any process or procedure developed to transform a set of input elements like men, materials, capital, information and energy into a specified set of output elements like finished products and services in proper quantity and quality.
2. The essence of production is the creation of goods, may be by the transformation of raw material or by assembling so many small parts.

B. Production System :

1. Production system is an intentional act of producing something.
2. Production system involves in producing goods with the help of an efficient management, utilizing land, labour, machines, capital and materials.
3. A production system constitutes an efficient process with an organized procedure for accomplishing the transformation of input elements to useful output products.

Que 1.2. Explain different types of production systems with appropriate examples.

Answer

Types of production systems are as follows :

A. Intermittent System :

1. In this system, the goods are manufactured specially to fulfill orders made by customers rather than for stock.
2. Intermittent production systems are those where the production facilities are flexible enough to handle a wide variety of products and sizes.

a. Features of an Intermittent System :

1. Demand can be discontinuous.
2. All operational stages may not be balanced.
3. Elaborate sequencing and scheduling is required.
4. Needs high investment.
5. Planning, routing and scheduling changes with fresh orders.
6. Storage is necessary at each stage of production process.
7. Can adjust to new situation and specification.
8. Inspection is not in line with production.

b. Types of Intermittent System : There are two types of intermittent system :

- i. Job Production or Project Type Production :** In this system, the goods are produced to definite customer's orders.

Example : Ship building, dam construction, bridge building, book printing, etc.

- ii. Batch Production :** The items are processed in lots or batches unlike job type system where one item is produced during each production run.

Example : Biscuit and confectionery and motor manufacturing, medicines, tinned food and hardware like nuts and bolts etc.

B. Continuous System :

1. In this system, the items are produced for the stocks and not for specific orders.
2. Here the inputs are standardized and a standard set of processes and sequence of processes can be adopted. In continuous manufacturing system each production run manufactures in large lot.

a. Features of Continuous Systems :

1. There must be continuity of demand.
2. The product must be standardized.
3. Material should be as per the specifications and delivered in time.
4. All operational stages in the process must be balanced.
5. Work must conform to quality standards.
6. Appropriate plant and equipment must be provided.
7. Maintenance must be by anticipation and not by default.
8. Inspection must be in line with production.

b. Types of Continuous System : There are two types of continuous system :

- i. Mass Production :** Here items are produced in large quantities and much emphasis is not given to consumers orders. Uniform and

uninterrupted flow of material is maintained through predetermined sequence of operations.

Example : Newspapers and magazines etc.

- ii. **Process Production :** This system is analogous to mass production system with more stress on automation in production process. The volume of production is very high.

Example : Process manufacturing goods include food, beverages, refined oil, petroleum, pharmaceuticals, chemicals and plastics, etc.

Que 1.3. Differentiate between intermittent and continuous production process.

Answer

S. No.	Intermittent Production Process	Continuous Production Process
1.	Same product is not produced continuously.	Same product is produced continuously.
2.	Items produced for order.	Items produced for stock.
3.	Production process is flexible.	Process is not flexible.
4.	Equipment used for limited time.	Regular use of equipment.
5.	Wide range of products can be produced.	Only particular type of product is produced.
6.	Smaller scale of production.	Large scale of production.
7.	Planning and control operations are complicated and tedious.	Planning and control operations are simple and easy.
8.	Capital investment may be low.	Capital investment is high.
9.	Change in location is easy.	Change in location is difficult.
10.	Product and process are not standardized.	Product and process are standardized.

Que 1.4. Differentiate between job production, batch production and mass production.

Answer

S. No.	Mass Production	Batch Production	Job Production
1.	Quantity produced is very large.	A limited batch quantity is produced.	One or few products are produced.
2.	Product is highly standardized.	Product is standardized.	As specified by the customer.
3.	Mostly single purpose machines and special purpose machines are used.	Special purpose machines and general purpose machines are used.	General purpose machines are used.
4.	Production planning is done thoroughly.	Production planning is necessary for each batch.	Production planning is done for each product.
5.	Product layout is used.	Combination of process and product layout is used.	A process layout or layout by fixed position is used.
6.	Scheduling is fixed.	Scheduling is done for each batch.	Scheduling is prepared for each job.
7.	Control function is easy.	Control function is sometimes easy.	Controlling is difficult.
8.	Semi-skilled workers are sufficient.	Semi-skilled workers are sufficient.	Highly skilled workers are needed.
9.	Unit cost is less.	Unit cost is high.	Unit cost is very high.
10.	Supervision is easy.	Supervision is not that easy.	Supervision is difficult.

Que 1.5.

Define productivity. State its importance giving suitable examples.

Answer**A. Productivity :**

1. Productivity is a ratio of actual output (production) to what is required to produce it (inputs).
2. Output means the amount produced or the number of items produced and inputs are the various resources employed, for example, land, building, equipment and machinery, materials, labours, etc.

$$\text{Productivity} = \frac{\text{Output}}{\text{Input}}$$

B. Importance of Productivity :

1. Productivity is a tool required in evaluating and monitoring the performance of an organization, especially a business organization.

2. Proper use of productivity measures can give the manager an indication of how to improve productivity: either increase the numerator of the measure, decrease the denominator, or both.
3. Productivity measures can be used to compare its performance with similar firms and competitors, compare performance among different departments within the firm.
4. Example : If two firms have the same level of output, but one requires less input leads to a higher level of productivity, that firm will be able to charge a lower price and increase its market share or charge the same price as the competitor and enjoy a larger profit margin.

Que 1.6. What are the factors affecting productivity.

Answer

Following are the factors affecting productivity :

- a. Technological Development :** Technical factors including the degree of mechanization, technical know-how, raw materials, layout and the methods and techniques of work determine the level of technological development in any industry.
- b. Individual Factors :** Individual factors such as knowledge, skill and attitude also affect the productivity of industry.
- c. Organization Factors :** Organization factors include various steps taken by the organization towards maintaining better industrial relations such as delegation and decentralization of authority, participative management, worker's participation in management, organizational efficiency, proper personnel policies relating to selection, placement, promotion, wage salary levels, incentives, merit rating, job evaluation, training and provision for two-way communication, supervision, etc. These factors also influence motivation.
- d. Work Environment :** The importance of proper work environment and physical conditions on the job has been emphasized by industrial psychologists and human engineers. Better work environment ensures the greatest ease at work through better ventilation and light arrangement, improved safety devices, reduction in noise, introducing suitable rest-pause, etc.

Que 1.7. What are the basic objectives of productivity measurement ? Explain different kind of productivity measurement.

Answer

A. Objectives of Productivity Measurement :

1. To study performance of a system over time.
2. To have relative comparison of different systems for a given level.

3. To compare the actual productivity of the system with its planned productivity.

B. Kind of Productivity Measurement :

- a. **Land Productivity :** The productivity of land and building is said to have increased if the output of goods and services within that area is increased.
- b. **Material Productivity :** Output can be measured in total quantity produced and material can be measured in terms of cost of material required to produce that output.

$$\text{Material productivity} = \frac{\text{Number of units produced}}{\text{Cost of material}}$$

- c. **Labour Productivity :** Output can be measured in total quantity produced and labour can be measured in total man hours required to produce that output.

$$\text{Labour productivity} = \frac{\text{Number of units produced}}{\text{Man hours utilized}}$$

- d. **Machine Productivity :** Output can be measured in total quantity produced and machine can be measured in total machine hours required to produce that output.

$$\text{Machine productivity} = \frac{\text{Actual output}}{\text{Actual machine hours utilized}}$$

e. Capital Productivity :

1. Capital productivity may be described as the ratio between the amount produced and the amount of capital used for that production.
2. To measure productivity we have to think in terms of time, since it is the output of goods or services from a machine or from a worker in a given number of machine hours.
3. So, capital productivity is the ratio of turn over to total machine hours required to produce that turn over.

$$\text{Capital productivity} = \frac{\text{Turn over}}{\text{Actual machine hours utilized}}$$

Que 1.8.

What are the benefits of increasing productivity to the workers and management ?

Answer

Benefits of increasing productivity to the workers and management are as follows :

A. For Management : It helps management :

1. To earn good profit because of reduction in costs.

2. To sell more, to earn profit.
3. To have better utilization of resources.
4. To stand better in the market.
5. Provide overall prosperity and reputation of the company.

B. For Workers :

1. Higher wages.
2. Better working conditions, improved morale.
3. Higher standard of living.
4. Job security and satisfaction.

Que 1.9. Differentiate between production and productivity.

Answer

S.No.	Features	Productivity	Production
1.	Definition	It is defined as the rate at which goods are produced.	It is defined as the act of manufacturing goods for their use or sale.
2.	Use	It is the utilization of resources to form goods.	It is the actual process of conversion.
3.	Work Done	It is the amount of work one gets for a certain spending cost.	It is the amount of work done or manufactured that is the output.
4.	Measurement	It is the measure of efficiency.	It is the measure of produced goods.

Que 1.10. Explain different ways to improve productivity.

Answer

Different ways to improve productivity are as follows :

- a. **Product Development :** It reduces work content due to design defects and excess material removal.
- b. **Specialization and Standardization :** It reduces idle time through variety reduction. Standardization reduces idle time due to short runs and due to increased batch size.

- c. **Market, Consumer and Product Research :** Market, consumer and product research ensure correct quality standards. Hence more rejects, rework and waste of material can be avoided.
- d. **Value Analysis :** Value analysis reduces excess work content due to design defects and excess material.
- e. **Process, Planning and Research :** It ensures selection of correct machines and thus reduces work content due to use of wrong machines. Process research ensures correct operation or process and hence excess work content due to inefficient process is reduced.
- f. **Operator Training :** It reduces work content due to bad working methods.

PART-2

Operations Strategies, Liability and Process Design.

Questions-Answers**Long Answer Type and Medium Answer Type Questions**

Que 1.11. Define operations management.

Answer

1. Operations management may be defined as a systematic approach to address all the issues pertaining to the transformation process that converts some inputs into output that are useful and could fetch revenue to the organizations.
2. It attempts to balance cost with revenue to achieve highest operating profits possible.
3. What operation management department do is, that they design a methods by which inputs is converted into output that is most beneficial to the organization.

Que 1.12. Write a short note on operation strategies.

Answer

1. Operations strategy is the collective concrete actions chosen, mandated, or stimulated by corporate strategy.
2. It is, of course, implemented within the operations function. This operations strategy binds the various operations decisions and actions into a cohesive consistent response to competitive forces by linking firm

policies, programs, systems, and actions into a systematic response to the competitive priorities chosen and communicated by the corporate or business strategy.

3. In simpler terms, the operations strategy specifies how the firm will employ its operations capabilities to support the business strategy.
4. Operations strategy has a long-term concern for how to best determine and develop the firm's major operations resources so that there is a high degree of compatibility between these resources and the business strategy.

Que 1.13. What do you mean by product liability ?

Answer

1. Product liability refers to the liability of any or all parties along the chain of manufacture of any product for damage caused by that product.
2. This includes the manufacturer of component parts (at the top of the chain), an assembling manufacturer, the wholesaler, and the retail storeowner (at the bottom of the chain).
3. Products containing inherent defects that cause harm to a consumer of the product, or someone to whom the product was loaned, given, etc., are the subjects of products liability suits.
4. Well-known examples of product liability suits include : Poorly designed cars, trucks, motorcycles and recreational vehicles, Unsafe power tools and appliances including everything from lawnmowers to heavy construction and farm machinery, Hazardous children's toys, clothing or other accessories such as car seats and cribs, and, Pharmaceuticals or other health care products that cause dangerous side effects or death.

Que 1.14. What are the requirements for process design ?

Answer

Following are the requirements for process design :

1. Detailed engineering drawings.
2. Knowledge of materials for manufacture.
3. Knowledge of manufacturing processes.
4. Knowledge of jigs and fixtures.
5. Knowledge of the relative costs of materials, processes and tooling
Manufacturing parameters (speed, feed etc.,) and costs
Knowledge of inspection/QA procedures and specifications.

PART-3

Factors Affecting Facility Location, Principle of Plant Layout Design, Types of Plant Layout, Computer Aided Layout Design Techniques, Assembly Line Balancing.

Questions-Answers**Long Answer Type and Medium Answer Type Questions**

Que 1.15. Explain facility location or plant location. Write the factors considered for the selection of a site.

Answer**A. Facility Location or Plant Location :**

1. Plant location means deciding a suitable location, area, place, etc., where the plant or factory will start functioning.
2. The problem of plant location arises when starting a new factory or during the expansion of the existing plant.
3. Plant location involves two main activities :
 - i. Selection of suitable geographic region.
 - ii. Selection of specific site in that region.

B. Factors Considered for the Selection of a Site : Following factors are considered while selecting a site for a plant :

- a. Nearness to Raw Material :** If raw material is bulky and heavy, the transportation charges will be high. So it is always better to locate the plant near the source of raw material.
- b. Land :** Topography, available area, cost, drainage and other facilities, probability of floods, earth quakes etc, influence the selection of site.
- c. Transport Facilities :** Normally, heavy amount is spent for transporting raw material and finished goods. Depending upon the type and size of raw material and finished goods, a suitable method of transport is selected (road, rail, water or air). Accordingly the plant location is selected.
- d. Availability of Labour :** Required number of labour must be available near the plant. They must be stable and must have right attitude towards work. The labour cost should be reasonable.
- e. Availability of Fuel and Power :** It is essential that continuous electric power is available in proper quantity at reasonable rates. Normally,

steel industries are located near coal fields to cut down the fuel transportation cost.

f. Other Factors :

1. Political and social environment,
2. Presence of supporting industries and services nearby,
3. Availability of hospitals, schools, marketing centres, banks, post offices etc.,
4. Housing facilities, and
5. Security.

Que 1.16. What are the objectives of a good plant layout ?

Answer

Following are the objectives of a good plant layout :

1. The movement of the workers should be minimum.
2. It should be flexible to accommodate changes in product design.
3. It should have space for future expansion.
4. It should lead to better working methods.
5. It should lead to lesser production time.
6. It should lead to reduced capital cost.
7. It should lead to better product quality.

Que 1.17. Explain the principle of plant layout design.

Answer

Principles of plant layout design are as follows :

- a. Integration :** All the production units like workers, machinery, raw material should be integrated and arranged in a logical manner.
- b. Minimum Movement and Handling :** The number of movements of workers and materials should be minimum. Material should be moved in bulk and not in small amounts.
- c. Material Flow :** The output at different work centres should be balanced. Material should flow smoothly without bottle necks, congestion and back tracking.
- d. Cubic Space Utilization :** In addition to using floor space, we must also utilize the empty space available upto the ceiling. More material can be accommodated in this manner. Raw material in boxes can be stacked one above the other.
- e. Safe Environment :** Working place should be safe, well ventilated, free from dust, noise, fumes, odors and other hazards. It leads to increased worker efficiency and better employer employee relationship.

- f. Flexibility :** In mass production models of products may change after some time. So it is better to keep the layout flexible. The machineries should be arranged in such a way that the changes in production process can be done with very less disturbance.

Que 1.18. Explain different types of plant layout with advantages and disadvantages.

Answer

Different types of plant layout are as follows :

a. Product or Line Layout :

1. A product or line layout is the one in which each machine is located according to the operation sequence required in producing one product or group of related products.
2. In this layout, materials are worked out into finished products through a series of integrated operations that is arranged in a straight line order.
3. The machines, under plan are thus located in U or line shape as shown in Fig. 1.18.1.

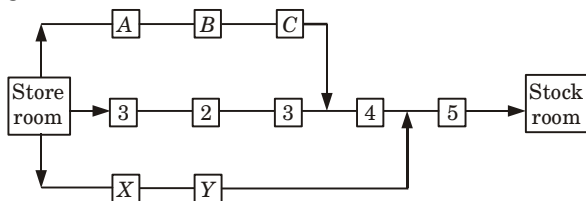


Fig. 1.18.1.

4. This type of layout is very popular in mass production.
5. In this layout only one product or one type of product is produced in an, operating area.

i. Advantages of Product of Line Layout :

1. It lowers the overall manufacturing time as product under it proceeds rapidly from operation without any handling delays.
2. Less skilled workers may be sufficient to operate machines.
3. Less space is needed for placing machines.
4. There is minimum of handling and transportation.
5. There is less work in process.

ii. Disadvantages of Product of Line Layout :

1. When the product or design changes, the layout of machinery also requires a change.
2. All machines in the arrangement cannot be used to their maximum capacity as in the case of process layout.

3. The manufacturing cost rises with a fall in the volume of production.
4. If one or more lines are running light, there is great machine idleness.
5. Specialized and strict supervision is needed.

b. Process or Functional Layout :

1. Process layout is one in which all machines of same type are grouped together.
2. In this, machines are arranged according to the nature or type of the operation.
3. Under this arrangement, the individual is responsible for carrying out a particular process and not a particular product as discussed in line type layout.
4. There is an assembly of similar operations in each department or section.
5. In a job order production factory, there is no standard product and it would be a repeated order.
6. Therefore, machines in this type of layout are generally arranged on functional basis.
7. This type is also called as an analytical layout as shown in Fig. 1.18.2.

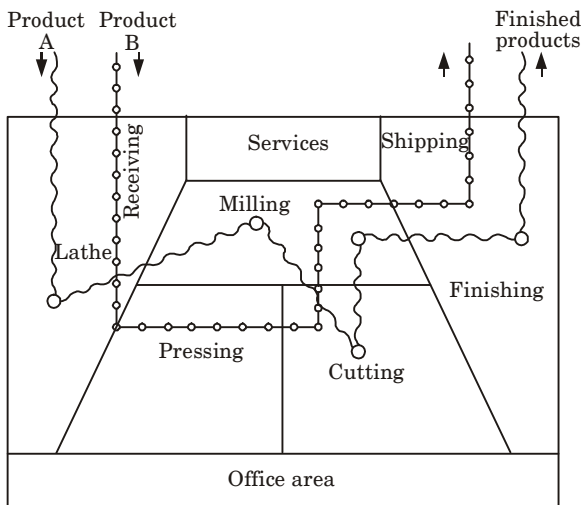


Fig. 1.18.2. Process or functional layout.

i. Advantages of Process or Functional Layout :

1. In similar jobs and machines, supervision is simple.
2. Less number of machines is required.

3. Great incentive for each worker is possible to raise the level of performance.
4. Better control on precision or complicated process is possible.
5. Layout is flexible.

ii. Disadvantages of Process or Functional Layout :

1. Material handling is more than in product layout.
2. Handling and back-tracking of materials is too much, thus leading to wasteful hauling of materials.
3. Planning and supervision of each department, workers and machines, are necessary. This makes production control difficult and costly.
4. More floor area is needed.

c. Fixed Position Layout (or) Static Product Layout (or) Project Layout :

1. This type of layout is applicable for manufacturing huge aircrafts, ship vessels and pressure vessels, as the product are too big or too heavy.
2. For these types of products it is convenient and economical to bring the tools, machine and men to the work place.
3. Men and equipment are moved towards the material which is fixed at one place and the completion of the product takes place where the material remains.
4. This is suitable in ship building, in-job welding shops, truss work, aircraft assembling, sculpturing, building construction etc.

i. Advantages of Fixed Position Layout :

1. Assurance of continuity of operations because the work is usually carried out by a group of workers.
2. Reduced total production cost.
3. Minimum material movement.
4. Possible to assign skilled workers to follow from the start to finish.
5. Flexibility in changing the product variety.

ii. Disadvantages of Fixed Position Layout :

1. Machine and tools etc, take more time to reach the work place.
2. Necessity of highly skilled workers.
3. Requirement of complicated jigs and fixtures in fixing jobs and tools etc.
4. Low content of progress.
5. Low utilization of labour and equipment.

Que 1.19. Explain in brief about computer aided layout design.

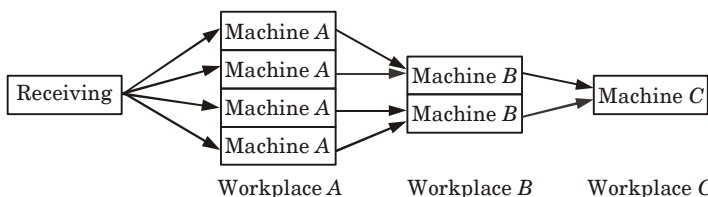
Answer

1. The key element of computer aided layout design is the representation and manipulation of the following three types of information :
 - a. **Numeric Information** : Space required for an activity, total flow between two activities.
 - b. **Logic Information** : Preferences of the designer, *i.e.*, the activity relationship chart.
 - c. **Graphical Information** :
 1. Drawing of the block plan.
 2. In computerized methods of layout design, we have two types of algorithms, *i.e.*,
 - i. Constructive type algorithm.
 - ii. Improvement type algorithm.
 3. Constructive algorithms are of following types :
 - i. Automated layout design program (ALDEP).
 - ii. Computerized relationship planning (CORELAP).

Que 1.20. What is line balancing ? Explain it.

Answer

1. Line balancing in a layout means balancing the production or assembly line particularly in product layout.
2. It may arise due to the fact that the production capacity of each machine in the sequence is not identical.
3. For example, suppose there are three work stations *A*, *B* and *C* with production capacities of 25, 50 and 100 pieces per hour.
4. The workstations *B* and *C* will be idle 50 per cent of the time. Such a layout is unbalanced and requires balancing.



5. To balance the line the production capacities of workstations *A* and *B* will have to be increased to match with the maximum capacity work station.

6. This will permit all stations to work to their maximum capacities. Thus line balancing for 100 units per hour at workplace A will be achieved by arranging 4 machines at workplace A, and two machine at place B.
7. The main objective is to distribute tasks evenly over the workstations to minimize the idle time of men and machines.

PART-4

Material Handling Principles, Types of Materials Handling Systems, Method of Process Planning, Steps in Process Selection, Production Equipment and Tooling Selection, Group Technology, and Flexible Manufacturing.

Questions-Answers**Long Answer Type and Medium Answer Type Questions**

Que 1.21. Define material handling. Write its importance.

Answer**A. Material Handling :**

1. It refers to the movement of materials from the store room to the machine and from one machine to the next during the process of manufacture.
2. Material handling is the art and science involving the movement, packaging and storing of substance in any form.
3. Material handling includes the movement of the material either manually or mechanically, either as a single item in batches at a time within the plant.

B. Importance of Material Handling :

1. The material handling problem must be studied at the time of planning the various machines and tools before the erection of factory building.
2. Materials handling is an essential consideration in designing new plants.
3. Several existing plants can be modified by the application of modern material handling devices.

Que 1.22. What are the functions of material handling ?

Answer

Functions of material handling are as follows :

1. The movement and positioning of purchased materials for the purpose of storage.
2. The internal transportation of materials between the place of storage and its place of use.
3. The movement of materials within departments for purpose of temporary storage or positioning for use at the machine of work place.
4. The movement and positioning of finished stock of the purpose of the stocking or sale.

Que 1.23. What are various types of material handling devices ?

Answer

Various types of material handling devices are as follows :

a. Industrial Trucks :

1. These are a large variety of powered and non-powered equipment used for transporting material and equipment on the shop floor.
2. This class of equipment includes fork-lift trucks, hand carts, and tractor trailer rigs.
3. Trucks are normally driven by a human operator and are useful for intermittent moves over varying paths but require adequate aisles.

b. Automated Guided Vehicles (AGVs) :

1. These are battery powered, driverless vehicles for automatic transport of parts and tooling on the shop floor.
2. These move on fixed paths laid underneath the factory floor and transport material from the workstations to storage locations, etc.

c. Conveyors :

1. These can be used for moving materials over a fixed path to specified locations.
2. It transports materials of relatively uniform size and weight with moderate to high frequency.
3. Conveyors can be used to move material, as well as position fixture for workers along a production line.

d. Cranes and Hoists :

1. These are overhead lifting devices that are often used for intermittent movement of large and heavier equipment within a fixed space.
2. Hoists lift material vertically while suspended from a hook.
3. Cranes move horizontally over guide rails with the product being suspended from a hoist when the crane moves.

Que 1.24. Explain the principles of material handling.

Answer

Principles of material handling are as follows :

- a. **Planning** : Principle of planning in all material handling activities is needed for efficient operation.
- b. **System Analysis** : Efforts should be made to integrate various activities such as receipt of raw material and finished goods, storage, inspection, package and transportation.
- c. **Material Flow** : Immediate flow of material leads to better plant layout.
- d. **Simplification** : By combining or eliminating unnecessary movement of the product or equipment, handling could be simplified.
- e. **Gravity** : As far as possible force of gravity should be utilized to move materials.
- f. **Space Utilization** : The space allotted for the plant should be effectively utilized for minimum movement of materials.
- g. **Unit Size** : The increase of quantity and size of the unit in transportation should be encouraged.
- h. **Mechanization** : Handling operations should be simplified by mechanization.
- i. **Automation** : Handling should be adopted in production and handling.

Que 1.25. What are the types of material handling systems ?

Answer

Types of material handling systems are as follows :

- a. **Manual Handling** :
 - 1. In factories, where the work is of repetitive nature, the jobs can be allowed to accumulate by the operator at one place, till it is worthwhile to get them carried away by a labourer either singly or in bundles, boxes, bags and trays.
 - 2. Here, a labourer acts as a handling device in bringing the raw materials for the operator and carrying away the finished goods.
 - 3. In this method, gravity assists in manual transport. For this purpose, trolleys, wheel barrows, handcarts etc, can be used.
- b. **Mechanical Handling** :
 - 1. There can be three major divisions of mechanical handling equipment such as :

i. Lifting and Lowering Devices :

1. Block and tackle,
2. Wineries,
3. Hoists,
4. Elevators, and
5. Pillar Crane.

ii. Transporting Devices :

1. Hand truck,
2. Wheeler or box truck or casters,
3. Narrowgauge mine tall road, and
4. Car-puller, trailers.

iii. Combination Devices :

1. Spiral chute,
2. Crane truck,
3. Trolley,
4. Form way skid, and
5. Low lift truck.

iv. Over Head Moments :

1. Jib cranes,
2. Overhead skid plant,
3. Gantry cranes,
4. Monorails, and
5. Bridge cranes.

Que 1.26. Write a short note on process planning.

Answer

1. Process planning means the preparation of detailed work plan.
2. It means the planning of production process.
3. It determines the most economical method of performing an activity.
4. The following details are planned in process planning :
 - i. The sequence of operations.
 - ii. The machines used for each operation.
 - iii. Tools and the equipment used.

- iv. Requirements of material.
- v. The grade of workmen required.

Que 1.27. Explain steps involved in process selection.

Answer

Steps involved in process selection are as follows :

- a. **Selection of Process :** The most economical method should be selected for converting raw material into finished product. The relation also depends on the following factors :
 - i. **Delivery Schedule :** If delivery has to be made quickly even costlier process may have to be selected.
 - ii. **Availability of Machine :** If machines in which cost of production is less are already loaded, we may have to select other machines.
 - iii. **Quantity :** When less quantity is needed, machines which have high cost of setting cannot be selected. We may have to select less efficient machines.
 - iv. **Quality :** The process which can give the required quality can only be selected.
- b. **Selection of Material :** The material should be of right quality and chemical composition. The shape and size should be such that the scrap is minimum :
- c. **Selection of Jigs, Fixtures :** Suitable jigs and fixtures should be used to give higher productivity and reduce cost of production.
- d. **Time Calculation :** Set up time and standard time for each operation is calculated with the help of data available from work study.
- e. **Process Sheet :** All the above particulars are entered in a printed process sheet.

Que 1.28. Discuss the production equipment and tool selection for the component shown in Fig. 1.28.1 undercut diameter is 12 mm.

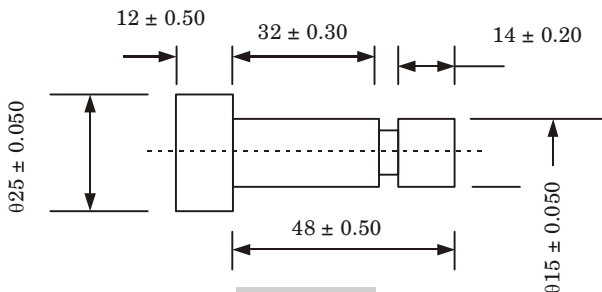


Fig. 1.28.1.

Answer

Production equipment and tool selection for the component is as follows :

a. Evaluation of Process and Machine Selection :

1. As stated in the problem, the process identified is turning and the machine tool is a small bench lathe. This limits the tools to select from to those we have in machine shop.

b. Analysis of Machining Operations :

1. The operations identified are facing, roughing, finishing and parting off. From this, two specific tools can be identified :
 - i. Turning/facing tool- facing, roughing and finishing;
 - ii. Parting off tool- parting off

c. Analysis of Workpiece Characteristics :

1. The fact that the workpiece material is brass means that HSS tooling is more than sufficient to carry out all operations. This is due to brass being highly machinable material.
2. However, in terms of workpiece and tool geometry, there are two issues to be considered. In terms of the facing and roughing out, a left-handed tool will not be able to completely finish the arc in the middle of the part.
3. There are two options that can be considered. The first is to produce half the arc with the left-handed tool and change to a right-handed tool for the other half.
4. However, it would be much simpler to use a contouring tool for the complete arc. Furthermore, a contouring tool will be required for the chamfered groove to the left-hand end of the part.
5. Therefore, it makes sense to use the contouring tool for both features, rake angles permitting, as this uses the least number of tools.

d. Tooling Analysis :

1. From the above stages, the following tooling list and operation description can be generated :
 - i. Facing: left-hand turning tool.
 - ii. Roughing: left-hand turning tool.
 - iii. Finishing: contouring tool.
 - iv. Parting off: parting-off tool.
 - v. Face the end and rough out the excess material with the left-hand turning tool.

2. The majority of the finish turning can be carried out with the left-hand turning tool.
3. However, the radius and the chamfered groove will be machined with the contour tool and finally the part will be cut from the billet by the parting off tool.

Que 1.29. Define group technology. Enumerate its benefits and disadvantages.

Answer

A. Group Technology :

1. Group technology is a manufacturing philosophy in which similar parts are identified and grouped together to take advantage of their similarities in design and production.
2. Similar parts are arranged into part families, where each part family possesses similar design and/or manufacturing characteristics.
3. For example, a plant producing 1000 different part members may be able to group the vast majority of these parts into 30 or 40 distinct families.

B. Benefits of Group Technology :

1. GT promotes standardization of tooling, fixturing, and setups.
2. Material handling is reduced because the distances within a machine cell are much shorter than within the entire factory.
3. Process planning and production scheduling are simplified.
4. Setup times are reduced, resulting in lower manufacturing lead times.
5. Work-in-process is reduced.
6. Worker satisfaction usually improves when workers collaborate in a GT cell.
7. Higher quality work is accomplished using group technology.

C. Disadvantage of Group Technology :

1. Lot of time and efforts are required initially to make part families.
2. Initial cost of implementation can be high.
3. If the range of products being manufactured by the company changes, of group technology codes have to be revised.
4. There are a number of GT codes but no single classification and coding system suits all applications.
5. There is lot of inconvenience for the machine shop to make conversion from conventional layout to group technology manufacturing cells.

Que 1.30. Discuss flexible manufacturing.**Answer**

1. A flexible manufacturing system (FMS) is a highly automated GT machine cell.
2. It consists of a group of processing workstations (usually CNC machine tools) interconnected by an automated material handling and storage system, and controlled by a distributed computer system.
3. The reason the FMS is called flexible is that it is capable of processing a variety of different part styles simultaneously at the various workstations, and the mix of part styles and quantities of production can be adjusted in response to changing demand patterns.
4. The FMS is not suited for mid-variety, mid-volume production range.
5. The initials FMS are sometimes used to denote the term Flexible Machining System. The machining process is presently the largest application area for FMS technology.
6. However, it seems appropriate to interpret FMS in its broader meaning allowing for a wide range of possible applications beyond machining.
7. A FMS relies on the principles of group technology.
8. No manufacturing system can be completely flexible. There are limits to the range of parts or products that can be made in an FMS.
9. Accordingly, a flexible manufacturing system is designed to produce parts (or products) within a defined range of styles, sizes, and processes.
10. A more appropriate term for FMS would be Flexible Automated Manufacturing System.
11. The use of the word “automated” would distinguish this type of production technology from other manufacturing systems that are flexible but not automated, such as a manned GT machine cell.
12. The word “flexible” would distinguish it from other manufacturing systems that are highly automated but not flexible, such as a conventional transfer line.

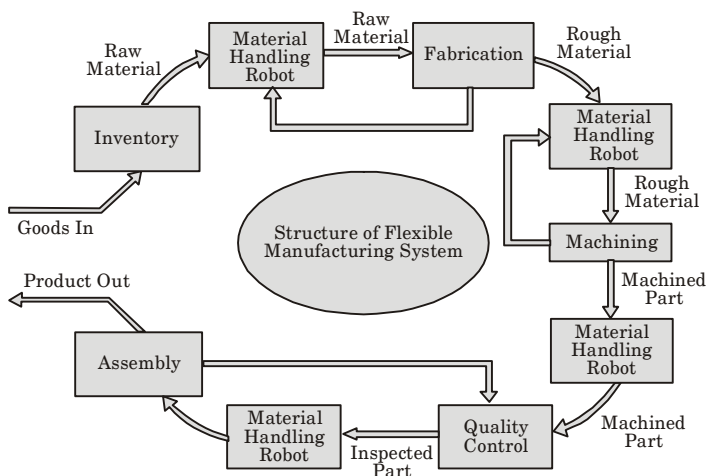


Fig. 1.30.1. Structure of flexible manufacturing system.

Que 1.31. Enlist the advantages and limitations of Flexible Manufacturing System.

Answer

A. Advantages of FMS : The FMS provides following advantages :

1. Higher production,
2. Higher machine utilization,
3. Reduced in process inventory,
4. Lower manufacturing lead times,
5. Greater flexibility in production scheduling,
6. Higher labour utilization,
7. Decreased direct and indirect labour cost,
8. Reduced cycle time,
9. Improved product quality, and
10. Reduced space requirement.

B. Disadvantages or Limitations of FMS :

1. Limited ability to adapt to changes in product or product mix (e.g., machines are of limited capacity and the tooling necessary for products, even of the same family, is not always feasible in a given FMS).

2. Substantial pre-planning activity.
3. Expensive, costing millions of dollars.
4. Technological problems of exact component positioning and precise timing necessary to process a component.
5. Sophisticated manufacturing systems.



2

UNIT

Production Planning and Control

CONTENTS

- Part-1** : Production Planning and Control : 2-2A to 2-11A
Forecasting Techniques,
Causal and Time Series Models,
Moving Average, Exponential Smoothing,
Trend and Seasonality
- Part-2** : Aggregate Production Planning, 2-11A to 2-15A
Master Production
Scheduling, Materials
Requirement Planning
(MRP) and MRP II
- Part-3** : Routing, Scheduling and 2-15A to 2-20A
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of JIT Manufacturing System
- Part-4** : Project Management : 2-20A to 2-29A
Project Network Analysis,
CPM, PERT and Project Crashing

PART- 1

Production Planning and Control : Forecasting Techniques, Causal and Time Series Models, Moving Average, Exponential Smoothing, Trend and Seasonality.

CONCEPT OUTLINE

Production Planning and Control : Production planning and control is the process of planning production in advance of operations, establishing the exact route of individual item part, or assembly, setting starting and finishing dates for each important item, assembly or the finished product, and releasing the necessary order as well as initiating the required follow up to effectuate the smooth functioning of the enterprise.

Causal Model : The causal model is broader in the number of factors that are analyzed when determining the outcome of the forecasting exercise. This method is useful when we need to apply several different components to the analysis in order to receive a well rounded forecast.

Time Series Models : A time series is a set of measurements of a variable that are ordered through time.

Questions-Answers**Long Answer Type and Medium Answer Type Questions**

Que 2.1. Define production planning and state its objectives ?

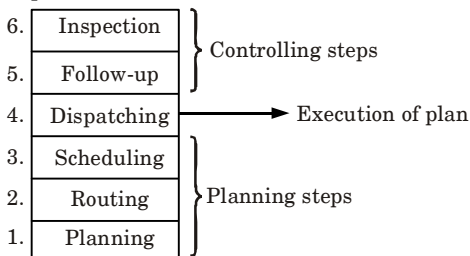
Answer**A. Production Planning :**

1. Production Planning is concerned with the determination, acquisition and arrangement of all facilities necessary for future operations.
2. Production planning means to fix the production goals and to estimate the resources which are required to achieve these goals.
3. It prepares a detailed plan for achieving the production goals economically, efficiently and in time.

B. Objectives of Production Planning :

1. Effective utilization of resources.

2. Steady flow of production.
3. Estimate the resources.
4. Ensures optimum inventory.
5. Coordinates activities of departments.
6. Minimize wastage of raw materials.
7. Improves the labour productivity.
8. Reduces the production costs.

**Que 2.2.**

What are the various steps involved in production planning and control ?

Answer

Steps in production planning and control are as follows :

a. Planning :

1. For planning of productive operations in detail, the planning department will receive full information from management about the quantity to be produced and the dates when delivery has been promised to customers.
2. The planning department will also get the necessary engineering and drawing specifications from the engineering department.

b. Routing :

1. The objective of routing is to find out the best and the cheapest sequence of operations.
2. While preparing the route card, it must be kept in mind that machines in the plant are operated at their full capacity; and manpower and other facilities are best utilized.

c. Scheduling :

1. Scheduling involves the preparation of a time-table, indicating the total time needed for the manufacture of a product as also the time expected to be spent at each machine and process.
2. In preparing schedules, the persons concerned will have to take into consideration the various types of orders on hand and the dates by which their completion has been promised.

d. Dispatching :

1. Procurement of necessary tools, jigs and fixtures etc., before they are actually required by the workmen.
2. Giving workers the necessary work orders, instructions, drawings etc., for initiating the work.

e. Follow-Up (or Checking the Progress) :

1. Follow-up is the control aspect of production planning and control.
2. It involves taking steps to check up whether work proceeds according to plans and how far there are variances from standards; and also taking necessary corrective steps to set things in order.

f. Inspection :

1. Inspection is the quality control aspect of production planning and control.
2. It ensures that goods produced are of the right quality.
3. The inspectors may inspect materials, semi-finished and finished products either at the work bench or in special laboratories or testing rooms.

Que 2.3. What do you mean by forecasting? What is the purpose of forecasting?

Answer**A. Forecasting :**

1. Forecasting means estimation of type, quantity and quality of future work e.g. sales etc.
2. Forecast represents a commitment on the part of the sales department and each of its divisions of expected sales. It becomes a goal against which the effectiveness of the sales department will be measured.
3. Forecasting plays a crucial role in the development of plans for the future.

B. Purpose (or Need) of Forecasting :

Purposes of forecasting are as follows :

1. It determines the volume of production and the production rate.
2. It suggests the need for plant expansion.
3. It emphasizes the need for product research development.
4. It helps establishing pricing policies.
5. It helps deciding the extent of advertising, product distribution, etc

Que 2.4. Discuss the forecasting techniques.

Answer

1. Forecasting methods can be classified as 'qualitative' or 'quantitative'. The qualitative methods use personal judgment and involve qualities like intuition and experience as the basis of forecasts, and subjective by their very nature.
2. On the other hand, quantitative methods are objective in nature and they employ numerical information as the basis of making forecasts.
3. In quantitative methods, a forecast can be developed using time series method or casual method.
4. The time series methods attempt to predict the future values using the historical data. The objective is to discover a pattern in the historical data and then extrapolate this pattern into the future, the forecast is based solely on past values of the variable that we are trying to forecast and/or on past forecast errors.
5. Causal forecasting methods are based on the assumption that the variable we are trying to forecast exhibits a cause-effect relationship with one or more other variables.

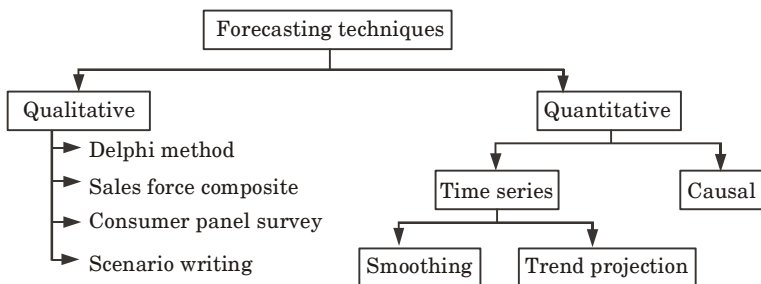


Fig. 2.4.1. An overview of forecasting techniques.

Que 2.5.

Explain forecasting using linear regression analysis.

Answer

1. The simple regression analysis is employed when there is one independent variable.
2. Here, an estimate of the dependent variable, say y is made corresponding to a given value of the independent variable, say x by placing the relationship between the two variables in the form of a regression line.
3. Using the least square method of forecasting, the estimated regression equation

$$y_e = a + b x$$

Where,

y_e = Estimated (forecast) value of dependent variable,

a = y -intercept of the regression line,

b = Slope of the regression line,

x = Independent variable,

4. As in the case of trend line, the values of a and b are obtained as follows :

$$b = \frac{\sum x y - n \bar{x} \bar{y}}{\sum x^2 - n (\bar{x})^2} \text{ and } a = \bar{y} - b \bar{x},$$

Where,

\bar{x} = Mean value of the independent variable,

\bar{y} = Mean value of the dependent variable,

n = Total number of observations.

b = Regression coefficient.

Que 2.6.

A manufacturer of optical lenses has the following data on the cost per unit (in Rs.) of a certain custom made lenses and the number of units made in each order :

Order No.	:	1	2	3	4	5	6
Number of units	:	1	3	5	7	10	12
Cost per unit	:	58	52	46	40	37	22

Obtain the regression equation on the cost per unit. Use this equation to estimate the cost of 15 units of lenses.

Answer

- To Find :**
- Regression equation of cost per unit.
 - Cost of 15 unit of lenses.

- Let the cost of an optical lense is denoted by y and the number of units of lenses by x . Then, we are to fit the equation of regression line y on x , $y_e = a + b x$.
- The calculations are shown in table given below :

Order	x	y	xy	x^2
1	1	58	58	1
2	3	52	156	9
3	5	46	230	25
4	7	40	280	49
5	10	37	370	100
6	12	22	264	144
Total	38	255	1,358	328

3. We have, $\bar{x} = \frac{\Sigma x}{n} = \frac{38}{6} = 6.33$, and $\bar{y} = \frac{\Sigma y}{n} = \frac{225}{6} = 42.5$.

$$b = \frac{\Sigma xy - n \bar{x} \bar{y}}{\Sigma x^2 - n (\bar{x})^2} = \frac{1,358 - 6 \times 6.33 \times 42.5}{328 - 6 \times (6.33)^2}$$

$$= - \frac{256.15}{87.58} = -2.92$$

$$a = \bar{y} - b \bar{x} = 42.5 - (-2.92) \times 6.33 = 42.5 + 18.48 = 60.98$$

4. The regression equation of y on x is given by,

$$y_e = 60.98 - 2.92x.$$

5. Estimation of cost, when $x = 15$,

$$y_e = 60.98 - (2.92) \times 15 = 17.18$$

Thus, for 15 units of optical lenses, the cost of a lense is Rs. 17.18.

Que 2.7. What is correlation analysis ?

Answer

1. This technique is employed when an organisation finds that the sale of its product has a remarkable relationship with the sales of a leading product of another organisation, e.g., sales of clutch plates is correlated with the sales of trucks produced, (Fig. 2.7.1).

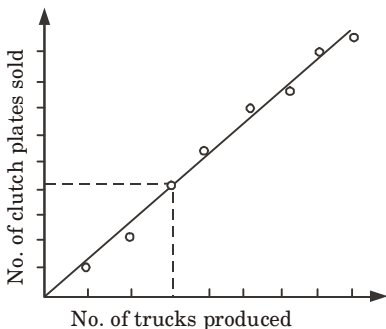


Fig. 2.7.1. Correlation data.

2. In correlation technique, total sales for an industry (e.g., truck manufacturing concern) is found and then based upon the market conditions, the volume of sale for one's own product (e.g., clutch plates) is predicted.

3. Such past data when plotted on the graph paper (Fig. 2.7.1) with line of best fit drawn, can predict sales estimate for future.
4. A correlation coefficient is a measure of the extent to which two variables (e.g. number of trucks sold and clutch plates sold) are associated a correlation coefficient is an indication of the extent to which the knowledge of the value of one variable is useful for the prediction of the value of the other.
5. Coefficient, r for two variables x and y

$$= \frac{\Sigma(x - \bar{x})(y - \bar{y})}{\sqrt{\Sigma(x - \bar{x})^2 \Sigma(y - \bar{y})^2}}$$

Where \bar{x} is the mean value of all the individual x values, and \bar{y} is the mean value of all the individual y values.

6. The formula measures linear correlation, *i.e.*,

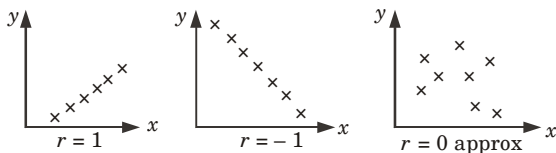


Fig. 2.7.2. Correlation.

Que 2.8. What are the components of time series models ?

Answer

Component of time series models are as follows :

a. Trend Component :

1. The time series data generally exhibit random fluctuations, but in spite of this the time series may still show gradual shifts or movements to relatively higher or lower values over a longer period of time.
2. The gradual shifting of the time series is referred to as the trend in the time series.
3. For example, change of technologies increase in prices over a period of years, the sales of a commodity may decrease over a period of years, because of better (improved) products coming in the market.

b. Cyclical Component :

1. Cyclic movements are recurrent upward or downward in time series, but the period of cycle is more than a year.
2. The sales of a company, for example, may be high because the level of economic activity may be high.
3. Similarly the sales may be low due to overall subdued economic activity.

c. Seasonal Component :

1. In time series the fluctuations that occur periodically-the movements recurring within a definite period, may be every week, or month or quarter with reasonably high degree of predictability are called seasonal components.
2. For example, daily traffic volume data show within-the-day seasonal behaviour, with peak levels during rush hours, moderate flow during the rest of the day, and light flow from midnight to early morning.

d. Irregular Component :

1. The fluctuations in time series that are short in duration, erratic in nature and follow no regularity in occurrence pattern are known as irregular variations.
2. These are also referred to as residual variations, since by definition they represent what is left out in a time series after trend, cyclic and seasonal variations.
3. Irregular or random fluctuations results due to the occurrence of unforeseen events like earthquakes, wars, floods, and so on.

Que 2.9. Explain moving average technique of forecasting.

Answer

1. The demand may often vary over time and only a certain period of data may be relevant for future forecast and all observations older than some specified period can be safely ignored.
2. This is the basis of moving averages where instead of taking the average of all historical data, only the latest N periods of data are used. As new data is available of all historical data, only the latest N periods of data are used. As new data is available the oldest data is ignored.
3. Thus

$$\begin{aligned} F(t+1) &= \text{Average of } N \text{ most recent pieces of data.} \\ &= [\text{Latest demand} + \text{next latest} + \dots + N^{\text{th}} \text{ latest}]/N \\ &= [D(t) + D(t-1) + \dots + D(t-N+1)]/N. \end{aligned}$$

Que 2.10. What is exponential smoothing technique of forecasting?

Answer

1. It is a special case of the weighted moving averages method, where the forecast for the next period is calculated as weighted average of all the previous observations.
2. It is based on the premise that the most recent observation is the most important for predicting the future value.

3. The basic exponential smoothing model is :

$$F_{t+1} = \alpha Y_t + (1 - \alpha)F_t$$

Where,

F_{t+1} = Forecast of the time series for period $t + 1$,

Y_t = Actual value of the time series in period t ,

F_t = Forecast of the time series for period t ,

α = Smoothing constant, $(0 \leq \alpha \leq 1)$.

4. The above equation is re-written as,

$$F_{t+1} = F_t + \alpha(Y_t - F_t).$$

The difference $(Y_t - F_t)$ represents the error in the previous forecast.

5. To start the calculations, we let F_1 equal the actual value of the time series in period 1, *i.e.*, $F_1 = Y_1$

Hence, the forecast for period 2 is,

$$F_2 = \alpha Y_1 + (1 - \alpha) F_1 = F_1 + \alpha (Y_1 - F_1) = Y_1 + \alpha (Y_1 - Y_1) = Y_1.$$

6. This shows that the exponential smoothing forecast for period 2 is equal to the actual value of the time series in period 1.

7. The forecast for period 3 is,

$$F_3 = \alpha Y_2 + (1 - \alpha) F_2 = \alpha Y_2 + (1 - \alpha) Y_1$$

Similarly,

$$\begin{aligned} F_4 &= \alpha Y_3 + (1 - \alpha) F_3 = \alpha Y_3 + (1 - \alpha) [\alpha Y_2 + (1 - \alpha) Y_1] \\ &= \alpha Y_3 + \alpha(1 - \alpha) Y_2 + (1 - \alpha)^2 Y_1 \end{aligned}$$

8. Hence F_4 is a weighted average of the first three time series values. The sum of the coefficient or weights, for Y_1 , Y_2 and Y_3 , equals 1.
9. A similar argument can be made to show that in general, any forecast F_{t+1} is a weighted average of all previous time series values.

Que 2.11. The following are weekly sales data, in thousands of units, for micro-computer disks :

113, 101, 98, 107, 120, 132, 110, 117, 112 and 125
Use $\alpha = 0.2$, $\alpha = 0.5$ and $\alpha = 0.8$ to produce an exponential smoothing model for these data. Which value of α produces better forecasts, assuming the initial forecast as 108 ? Explain.

Answer

- The forecasts using each of the above values are shown calculated in table.
- To illustrate for $t = 1$, let $F_1 = 108$. Now, with $Y_1 = 113$ and $\alpha = 0.2$, the forecast for $t = 2$ is : $F_2 = F_1 + 0.2(Y_1 - F_1)$, *i.e.*, $F_2 = 108 + 0.2(113 - 108) = 108 + 0.2 \times 5 = 109$.
- For each case, the absolute difference between actual and forecasted values are obtained and averaged to get *MAD*.

Week t	Sales (in'000) Y_t	$\alpha = 0.2$		$\alpha = 0.5$		$\alpha = 0.8$	
		F_t	$ Y_t - F_t $	F_t	$ Y_t - F_t $	F_t	$ Y_t - F_t $
1	113	108.0	5.0	108.0	5.0	108.0	5.0
2	101	109.0	8.0	110.5	9.5	112.0	11.0
3	98	107.4	9.4	105.8	7.8	103.2	5.2
4	107	105.5	1.5	101.9	5.1	199.0	8.0
5	120	105.8	14.2	104.4	15.6	105.4	14.6
6	132	108.7	23.3	112.2	19.8	117.1	14.9
7	110	113.3	3.3	122.1	12.1	129.0	19.0
8	117	112.7	4.3	116.1	0.9	113.8	3.2
9	112	113.5	1.5	116.5	4.5	116.4	4.4
10	125	113.2	11.8	114.3	10.7	112.9	12.1
11	—	115.6	—	119.6	—	122.6	—
		Total	82.3		91.0		97.4

4. From the above table,
- if $\alpha = 0.2$, then $MAD = 82.3/10 = 8.23$,
 - if $\alpha = 0.5$, then $MAD = 91/10 = 9.1$,
 - if $\alpha = 0.8$, then $MAD = 97.4/10 = 9.74$.
5. Since, MAD is found to be minimum for $\alpha = 0.2$, therefore, this smoothing constant is most preferable of these.

PART-2

Aggregate Production Planning, Master Production Scheduling, Materials Requirement Planning (MRP) and MRP II.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 2.12. Write a short note on following :

- Aggregate Production Planning, and
- Master Production Schedule (MPS).

Answer**a. Aggregate Production Planning :**

1. Aggregate planning is a high-level corporate planning activity.
2. The aggregate production plan indicates production output levels for the major production lines of the company.
3. The aggregate plan must be coordinated with the plans of the sales and marketing departments.
4. Because the aggregate production plan includes products that are currently in production, it must also consider the present and future inventory levels of those products and their component parts.
5. Because new products currently being developed will also be included in the aggregate plan, the marketing plans and promotions for current products and new products must be reconciled against the total capacity resources available to the company.

b. Master Production Schedule (MPS) :

1. The production quantities of the major product lines listed in the aggregate plan must be converted into a very specific schedule of individual products, known as the master production schedule (MPS).
2. It is a list of the products to be manufactured, when they should be completed and delivered, and in what quantities.
3. Products included in the MPS divide into three categories :
 - i. Firm customer orders,
 - ii. Forecasted demand, and
 - iii. Spare parts.
4. Proportions in each category vary for different companies, and in some cases one or more categories are omitted.
5. In the case of customer orders for specific products, the company is usually obligated to deliver the item by a particular date that has been promised by the sales departments.
6. In the second category, production output quantities are based on statistical forecasting techniques applied to previous demand patterns, estimates by the sales staff, and other sources.
7. The third category consists of repair parts that either will be stocked in the company's service department or sent directly to the customer.
8. The MPS is generally considered to be a medium range plan since it must take into account the lead times to order raw materials and components, produce parts in the factory, and then assemble the end products.

Que 2.13. What are the advantages and disadvantages of master production scheduling ? Write its applications also.

Answer**A. Advantages of Master Scheduling :**

1. It is simple and easy to understand,
2. It can be kept running (*i.e.*, current),
3. It involves less cost to make it and maintain,
4. It can be maintained by non-technical staff, and
5. A certain percentage of total weekly capacity can be allocated for rush orders.

B. Disadvantages of Master Scheduling :

1. It provides only overall picture, and
2. It does not give detailed information.

C. Applications of Master Scheduling :

1. In big firms, for the purpose of loading the entire plant,
2. In Research and Development organisations, and
3. For the overall planning in foundries, computer centres, repair shops, etc.

Que 2.14. What is material requirement planning ? What are the three inputs to the MRP processor ?

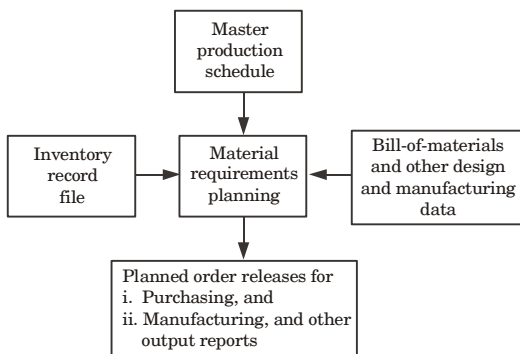
Answer**A. MRP :**

1. Material requirements planning (MRP) is a computational technique that converts the master schedule for end products into a detailed schedule for the raw materials and components used in the end products.
2. The detailed schedule identifies the quantities of each raw material and component item. It also indicates when each item must be ordered and delivered to meet the master schedule for final products.
3. MRP is often thought of as a method of inventory control. It is both an effective tool for minimizing unnecessary inventory investment and a useful technique in production scheduling and purchasing of materials.
4. MRP is the appropriate techniques for determining quantities of dependent demand items.
5. These items constitute the inventory of manufacturing : raw materials, work in process (WIP), components parts, and subassemblies.

B. Inputs to the MRP Processor :

1. The master production schedule,
2. The bill of materials file and other engineering and manufacturing data, and

3. The inventory record file.

**Fig. 2.14.1.** Structure of an material requirement planning system.

Que 2.15. Briefly discuss the manufacturing resource planning (MRP II).

Answer

1. Manufacturing resource planning can be defined as a computer based system for planning, scheduling, and controlling the materials, resources, and supporting activities needed to meet the master production schedule.
2. MRP II is a closed-loop system that integrates and coordinates the major functions of the business involved in production.
3. This means that MRP II incorporates feedback of data on various aspects of operating performance so that corrective action can be taken in a timely manner that is MRP II includes shop floor control.
4. MRP II can be considered to consist of three major modules, as illustrated in Fig. 2.15.1.
 - i. Material requirements planning, or MRP,
 - ii. Capacity planning, and
 - iii. Shop floor control
5. The MRP module accomplishes the planning function for materials, parts, and assemblies, based on the master production schedule, and it provides a factory production schedule that matches the arrival of materials determined by MRP.
6. Manufacturing resource planning is an improvement over material requirements planning because it includes production capacity and shop floor feedback in its computations.

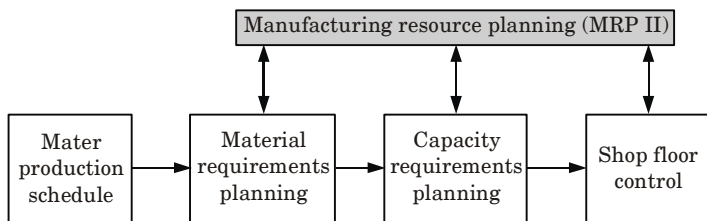


Fig. 2.15.1.

PART-3

Routing, Scheduling and Priority Dispatching, Concept of JIT Manufacturing System.

Questions-Answers**Long Answer Type and Medium Answer Type Questions**

Que 2.16. What do you mean by routing ? What is the procedure of routing ?

Answer**A. Routing :**

1. Routing indicates the flow of material inside the plant.
2. Routing indicates how, where and in what sequence, the work is done.
3. The objective of routing is to find out the best and the cheapest sequence of operations.
4. While preparing the route card, it must be kept in mind that machines in the plant are operated at their full capacity, and manpower and other facilities are best utilized.

B. Procedure of Routing :

1. Quantity to be produced is found out.
2. Available machine capacities and machine characteristics are found out.
3. Path of flow of material is decided.
4. Based on details available in process sheets, the route sheet is prepared.

Que 2.17. What is scheduling ? What are the objectives of scheduling ? Write its advantages.

Answer**A. Scheduling :**

1. Scheduling involves the preparation of a time-table, indicating the total time needed for the manufacture of a product as also the time expected to be spent at each machine and process.
2. In preparing schedules, the persons concerned will have to take into consideration the various types of orders on hand and the dates by which their completion has been promised.

B. Objectives of Scheduling :

1. To deliver the goods to the customer in time.
2. To make men, material and machine readily available for the production.
3. To make maximum use of man power and machine capacity.
4. To prevent overloading and under utilization of men and machines.
5. To keep minimum material in the process.

C. Advantages of Scheduling :

1. Minimizes the production cost.
2. Less investment of material in process.
3. Minimum material storage cost.
4. Customer satisfaction.
5. No over loading of men and machines.
6. No under utilization of men and machines.

Que 2.18. Explain the types of scheduling.

Answer

Types of scheduling are as follows.

a. Master Scheduling :

1. Master schedule gives the number of units of different products to be produced for the whole year.
2. It gives the units of production for every month for different products.
3. Master schedule is based on the basis of sales forecast.

b. Parts Scheduling :

1. Parts schedule gives the number of units of different parts to be produced for the given product.
2. The schedule is prepared for a month. It gives the details of production for every week.
3. Parts schedule is prepared on the basis of master schedule.

c. Machine Loading Schedule :

1. Machine loading schedule is the process of allocating work load for various machines.
2. It is a time table for the working of various machines. This schedule is prepared for a period of one week.
3. It gives details of machine loading for every day of the week. This scheduling is prepared on the basis of parts schedule.

Que 2.19. Write a short note on dispatching.

Answer**A. Dispatching :**

1. Dispatching is releasing of work order and other, documents to different departments to start production activities.
2. Procurement of necessary tools, jigs and fixtures etc., before they are actually required by the workmen.
3. Giving workers the necessary work orders, instructions, drawings etc., for initiating the work.
4. The different activities of dispatching are as follows :
 - i. Releasing the schedule for the production departments.
 - ii. Issuing work orders to start the production work.
 - iii. Releasing material issue order to the stores.
 - iv. Issuing move order for the movement of materials.

Que 2.20. What is the concept of JIT ? Explain its genesis.

Answer

1. JIT is a Japanese production management philosophy which has been applied in practice since the early 1970s in many Japanese manufacturing organizations.
2. This approach was first developed in Japan by Toyota Company, hence it is also known as 'Toyota manufacturing system.'
3. Just in time emphasizes waste reduction, total quality control and devotion to the customer.
4. One of the central ideas of this system is the elimination of waste from the manufacturing process. Its goal is to optimize processes and procedures by continuous pursuing waste reduction.
5. This involved reducing waste and using materials and resources in the most efficient possible manner.
6. This is achieved by a focus on a continuous stream of small improvements known in Japan as 'Kaizen' and has been recognised as one of the most significant elements of JIT philosophy.

7. JIT production is defined as a :

“Philosophy that focuses attention on eliminating waste by purchasing or manufacturing just enough of the right items just in time”.

8. This involves having the right items of the right quality and quantity in the right place and at the right time.

9. Toyota motor company identifies seven wastes as being the targets of continuous improvement in production processes. By attending to these wastes, improvement is achieved. They are :

a. Waste of Overproduction :

1. Eliminate by reducing setup times, synchronizing quantities and timing between processes, compacting layout, visibility, and so forth, make only what is needed now.

b. Waste of Waiting :

1. Eliminate through synchronizing work flow as much as possible and balance uneven loads by flexible workers or equipments.

c. Waste of Transportation :

1. Establish layouts and locations to make transport and handling unnecessary, if possible.

2. They rationalize transport and material handling that cannot be eliminated.

d. Waste of Processing Itself :

1. First question why this product should be made at all, then why each process is necessary.

2. Extend thinking beyond economy of scale or speed.

e. Waste of Stocks :

1. Reduce by shortening setup times and reducing lead times, by synchronizing work flows and improving work skills, and even by smoothing fluctuations in demand for the product.

2. Reducing all the other wastes reduces the waste of stocks.

f. Waste of Motion :

1. Study motion for economy and consistency.

2. Economy improves productivity and consistency improves quality.

3. First improve the motions, then mechanize or automate.

4. Otherwise there is danger of automating waste.

g. Waste of Making Defective Products :

1. Develop the production process to prevent defects from being made so as to eliminate inspection.

2. At each process accept no defects and make no defects. Make processes fail-safe to do this.

3. From a quality process comes a quality product automatically.

Que 2.21. Explain the characteristics of JIT system.

Answer

Characteristics of JIT system are as follows :

a. Pull System :

1. Purchase of the final product by the customer pulls output from the final stage of production, which in turn pulls output from the preceding stages of production.
2. Each production stage pulls output from the preceding stages when it is needed. Hence, a JIT system is considered a pull system.

b. Quality :

1. JIT systems require high quality levels for product design, production process and raw materials supplied by the vendors.
2. Also, workers are provided with adequate tools, training, support, encouragement and authority for ensuring production of high quality goods.

c. Small Lot Sizes :

1. This system use small lot sizes in the production process. It requires small deliveries from suppliers.
2. Small lot sizes permit greater flexibility in scheduling and reduce in-process inventory.
3. Flexibility enables quick response to changing customer demands.
4. Reduced inventory levels help to minimize holding costs, space and clutter.
5. Also smaller lots require less inspection and lower rework costs.

d. Quick Setups :

1. Setup procedures are simple and standardized to enable frequent and quick setups due to smaller lot sizes.

e. Production Smoothing :

1. To ensure a smooth flow of goods from the supplier to the final stage of production, all activities are carefully coordinated and changes to the production plan are minimized.

f. Suppliers :

1. Since this system requires high quality materials delivered on time and uses small lot sizes, it also requires reliable suppliers who are willing to ship high quality materials and parts on a regular basis.

g. Kanban Card :

1. Communication between a production stage and the preceding stages is carried out in various ways to ensure timely and smooth movement of parts and materials.

2. The Kanban card is a commonly used tool for communicating the need for the parts from a preceding production stage.
3. Without this card, which serves as an authorization, no part or lot can be moved.

Que 2.22. Write down the advantages and limitations of JIT system.

Answer

A. Advantages of JIT System :

1. Reduced inventory levels and manufacturing lead times.
2. Encouragement of worker participation in problem solving.
3. Improved relations with suppliers and smooth production flow by removing disruptions and in efficiency.
4. Overall better quality of whatever is produced.
5. Less scrap and less raw material, less work in process inventory.
6. Increased employee and equipment efficiency.
7. Less finished goods sitting.
8. Facility floor space is saved because there are no rework lines to correct production mistakes.

B. Limitations of JIT System :

1. Not able to meet any unforeseen demand.
2. Needs establishment of long term business partnership with suppliers.
3. Needs continuous and close evaluation and follow up of the whole process.
4. High risk is involved due to short term planning and a minimum level of inventory.
5. Suppliers of input materials need to be educated about the quality by the customers/company.

PART-4

*Project Management : Project Network Analysis,
CPM, PERT and Project Crashing.*

CONCEPT OUTLINE

Project Management : It is a scientific way of planning, implementing and controlling various aspects of project such as time, money materials, manpower and other resources with the intention of achieving the basic objective or goals including technical specification, cost and time schedule.

PERT : It helps in designing, planning, coordinating and decision making to accomplish the project economically in the minimum available time with limited available resources.

CPM : CPM uses networking principle for planning and controlling projects. It is very widely used next to PERT model.

Crashing of Operations : In order to find optimum duration which will result in minimum cost, crashing of network is done.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 2.23. What is a Project ? What are the stages of project management ?

Answer

A. Project :

1. It is defined as an organised programme of pre determined group of activities that are non routine in nature and that must be completed using the available resources within the given time limit.
2. According to Harison, "A project can be defined as a non routine, non repetitive, one-off undertaking, normally with discrete time, financial and technical performance goals".

B. Stages of a Project Management :

The main five stages of project management are as follows :

a. The Initiation :

1. The initiation phase will start as soon as giving the assignment to the project team member.
2. It includes overall project goal and ask the client or project owner as many question as possible, so the team members can plan the project efficiently.

b. Planning :

1. Once team members have initiated the project and gather all relevant information, they will begin planning the project.
2. The planning stage depends on the size of the project *i.e.*, how much information have to be organize and how large the team is.

3. The end result of planning should be a clear project plan or schedule from which everyone follows their assigned task.
- c. Scheduling or Execution :**
 1. After completion of planning, the team can begin executing the project against their assigned task.
 2. This is the stage where everyone actually starts doing the work.
 3. The project is officially kicked off from the execution stage with personal meeting to ensure everyone has all the necessary resources to begin execution of their part of the project.
- d. Monitor and Control :** While the project is in the execution stage, monitoring and controlling begins to ensure that project is moving along as planned.

Que 2.24. Explain in brief important characteristics of project.

Answer

Characteristics of a project are as follows :

- a. Objective :** Every project has specific objective. The project ceases to exist after objectives have been achieved.
- b. Life Span :** The life span representing the start and end of a project are specified in the objective.
- c. Uniqueness :** Every project is unique and is one unit with one responsible authority. However, there are many participants in the project.
- d. Team Work :** A team is constituted with member drawn from different disciplines, specialization, organizations and may be countries.
- e. Life Cycle :** A project has a life cycle consisting of conception, design, implementation and commissioning stages.
- f. Change :** A project is not rigid in life span. Changes occur throughout the life span of a project. Some of the changes may not have major impact. However, some changes can affect the earlier character or course of the project.
- g. Customer Specific :** A project is always customer specific. The customer gives various requirement and constraint within which the project has to be executed.
- h. Complexity :** A project is a complex set of activities relating to technology, machinery, material equipment and people, work culture and ethics, financial resources. Execution of the project in time by proper scheduling of different activities contributes to the complexity of project.
- i. Risk and Uncertainty :** Risk and uncertainty go hand and hand with the project. The degree of risk and uncertainty will depend upon the type of project.

- j. Optimization :** Project management concept has evolved with the aim of achieving optimal utilization of available resources.

Que 2.25. Describe the basic rules for drawing a network diagram.

Answer

Rules for drawing a network diagram are as follows :

1. Each activity is represented by one and only one arrow.
2. Each activity must be identified by its starting and end node which implies that :
 - i. Two activities should not be identified by the same completion events, and
 - ii. Activities must be represented either by their symbols or by the corresponding ordered pair of starting completion events.
3. Nodes are numbered to identify an activity uniquely. Tail node should be lower than the head node of an activity.
4. Between any pair of nodes, there should be one and only one activity, however more than one activity may terminate to a node.
5. Arrow should be kept straight and not curved or bent.
6. The logical sequence between activities must follow the following rules :
 - i. An event cannot occur until all the incoming activities into it have been completed.
 - ii. An activity cannot start unless all the preceding activities on which it depends have been completed.
 - iii. Dummy activities should only be introduced if absolutely necessary.

Que 2.26. Define critical path and its importance in network analysis.

Answer

A. Critical Path :

1. The sequence of critical activities in a network is called critical path.
2. The critical path is longest path in the network from the starting event to ending event and defines the minimum time required to complete the project.
3. The critical path is denoted by darker or double lines to distinguish it from the other non-critical paths.
4. The critical path has two principle features :
 - i. First, if the project has to be shortened some of the activities on that path must be shortened.

- ii. The variation in actual performance from the expected activity duration time will be completely reflected in one to one fashion in the anticipated completion of the whole project.

B. Importance of Critical Path in Network Analysis :

1. Analysis and breakdown the project in terms of specific activities and / or events.
2. Determine the independence and sequence of specific activities and prepare a network.
3. Assign estimates of time, cost or both to all the activities of the network.
4. Identify the longest or critical path through the network.
5. Monitor, evaluate and control the progress of the project by replanting, rescheduling and reassignment of resources.
6. The critical path of a project can change during the course of the project, due to uncertainties in completing the activities as per the original plan. For this purpose the network needs to be updated from time to time from the start of the project till the end of the project.

Que 2.27. Explain the terms : Total float, free float, independent float, slack, critical event, critical activities.

Answer

A. Total Float :

1. It may be defined as the amount of time by which completion of an activity could be delayed beyond the earliest expected completion time without affecting overall project duration time.

$$\begin{aligned} \text{2. Total Float, } TF_{ij} &= LS_{ij} - ES_{ij} = (L_j - t_{ij}) - E_i \\ &= L_j - E_i - t_{ij} \end{aligned}$$

Where, E_i = Earliest expected completion time of tail event.
 $=$ Earliest starting time for an activity (i, j) .

and L_j = Latest allowable completion time of head event.
 $=$ Latest finish time of an activity (i, j) .

3. Obviously, the total float of critical activities is always zero.

B. Free Float :

1. This is concerned with commencement of subsequent activity.
2. It may be defined as the time by which the completion of an activity can be delayed beyond the earliest finish time without affecting the earliest start of a subsequent activity.
3. Using notations given earlier, the free float for activity (i, j) can be expressed as follows :

$$\begin{aligned}
 FF_{ij} &= (E_j - E_i) - t_{ij} \\
 &= E_j - (E_i + t_{ij})
 \end{aligned}$$

C. Independent Float :

1. This is concerned with prior and subsequent activities.
2. It may be defined as the amount of time by which the start of an activity can be delayed without affecting the earliest start time of any immediately successor activities, assuming that the preceding activity has finished at its latest finish time.
3. Independent float of an activity (i, j) is given by :
Independent Float $(IF_{ij}) = (E_j - L_i) - t_{ij}$

D. Slack of an Event :

1. The basic difference between slack and float times is that slack is used for events only whereas float is applied for an activity.
2. For any given event, the event slack is defined as the difference between the latest event and earliest event times. For a given activity (i, j) let us define :

$$\text{Head slack (HS)} = L_j - E_j \text{ and}$$

$$\text{Tail slack (TS)} = L_i - E_i$$

3. We can represent all the floats defined earlier, in terms of head and tail slack as shown below :

$$\text{Total float} = L_j - E_i - t_{ij}$$

$$\text{Free float} = \text{Total float} - \text{Head slack}$$

$$= L_j - E_i - t_{ij} - (L_j - E_j)$$

4. Independent float = Free float - Tail slack
$$= E_j - E_i - t_{ij} - (L_i - E_i)$$

E. Critical Event :

1. The slack of an event is the difference between the latest and earliest event times or slack $(i) = L_i - E_i$.
2. The events with zero slack time are known as critical events.

F. Critical Activities :

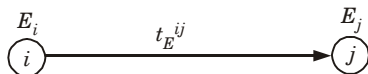
1. The difference between the least start time and earliest start time of an activity will indicate the amount of time by which the activity can be delayed without affecting the total project duration.
2. This difference is usually called the total float. Activities with zero total float are known as critical activities.

Que 2.28. Explain the following terms in PERT / CPM.

- | | |
|---------------------------|----------------------|
| i. Earliest time, | ii. Latest time, |
| iii. Total activity time, | iv. Event slack, and |

Answer

- i. **Earliest Time :** It is the time at which an event is accepted to be completed at the earliest.



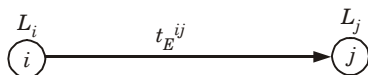
$$E_j = \text{Maximum of all } [E_i + t_E^{ij}],$$

Where,

E_i = The earliest expected time for event i , and

E_j = The earliest expected time for event j .

- ii. **Latest Time :** It is the time at which a particular event must be completed at the latest.



$$L_i = \text{Minimum of all } [L_j - t_E^{ij}],$$

Where,

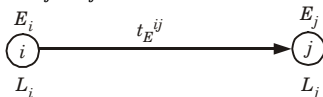
L_i = Latest allowable time for event i , and

L_j = Latest allowable time for event j .

- iii. **Total Activity Time :** It is defined as the time at which the project completed all its activities.

- iv. **Event Slack :** It is define as the difference between latest event and earliest event times. Mathematically, for a given activity (i, j) ,

$$\text{Head event slack} = L_j - E_j, \text{ Tail event slack} = L_i - E_i.$$



$$S_i = L_i - E_i$$

$$S_j = L_j - E_j$$

Que 2.29. Define PERT and relative terms.

- A. **Project Evaluation and Review Technique (PERT) :**

1. The main object in the analysis through PERT is to find out the completion for a particular event within specified date. If yes, what are the chances of completing the job ?
2. The PERT approach takes uncertainties into the account.
3. In this approach, three different time are associated with each activity : the optimistic time, the pessimistic time, and the most likely time.
4. These three times provide a measure of uncertainty associated with that activity.

B. Relative Terms :**a. The Optimistic Time :**

1. It is the shortest possible time in which the activity can be finished. It assumes that everything goes very well.
2. This is denoted by t_o (or a).

b. The Most Likely Time :

1. This represents the longest and is the estimate of the normal time the activity would take. This assumes normal delays.
2. If a graph is plotted between the time of completion and the frequency of completion in that time period then the most likely time will represent the highest frequency of occurrence. This is denoted by t_m .

c. The Pessimistic Time :

1. This represents the longest time the activity could take if everything goes wrong.
2. As in optimistic estimate this value may be such that only one in hundred or one in twenty will take time longer than this value. This is denoted by t_p .

d. Expected Time :

1. This is the average time an activity will take if it were to be repeated on large number of times and is based on the assumption that the activity time follows beta distribution.
2. This is given by the formula :

$$t_e = (t_o + 4t_m + t_p)/6$$

e. Variance : The variance for the activity is given by the formula :

$$\sigma^2 = [(t_p - t_o)/6]^2$$

Where, t_o is the optimistic time, t_p is the pessimistic time, t_m is the most likely time, t_e is the expected time and σ^2 is the variance.

Que 2.30. Describe in detail about crashing of operation.

Answer

1. In crashing following steps should be followed one by one :

Step 1 : Find critical path and normal project duration.

Step 2 : Find cost slope of each activity.

Step 3 : Select the activity with minimum cost slope and crash it first. While crashing, it should be remembered that it should not be crash beyond limit such that other paths become critical.

Step 4 : Select next higher cost slope with critical activity. While doing so, there may be one or more than one critical path. Then, one activity from each path should be crashed simultaneously by same amount of duration.

Step 5: Repeat the above steps unless total minimum cost and optimum duration is obtained.

Que 2.31. The following tasks have to be performed periodically on the heat exchangers in a refinery :

Task	Immediate predecessors	Time (days)
A	-	14
B	A	22
C	B	10
D	B	16
E	B	12
F	C	10
G	C	6
H	F, G	8
I	D, E, H	24
J	I	16

- Draw a network diagram of activities for the project.
- Identify the critical path. What is its length ?

Answer

- Network diagram :

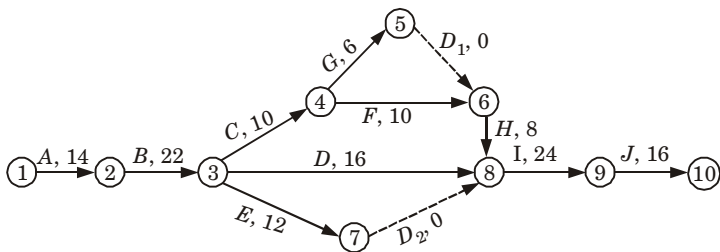


Fig. 2.31.1.

where, D_1 and D_2 are the dummy activities.

- Path (1 – 2 – 3 – 4 – 5 – 6 – 8 – 9 – 10) duration

$$= 14 + 22 + 10 + 6 + 0 + 8 + 24 + 16$$

$$= 100 \text{ days}$$
- Path (1 – 2 – 3 – 4 – 6 – 8 – 9 – 10) duration

$$= 14 + 22 + 10 + 10 + 8 + 24 + 16$$

$$= 104 \text{ days}$$
- Path (1 – 2 – 3 – 8 – 9 – 10) duration

$$= 14 + 22 + 16 + 24 + 16$$

$$= 92 \text{ days}$$

5. Path (1 – 2 – 3 – 7 – 8 – 9 – 10) duration

$$= 14 + 22 + 12 + 0 + 24 + 16$$

$$= 88 \text{ days}$$

6. Since, path (1 – 2 – 3 – 4 – 6 – 8 – 9 – 10) has maximum duration.

Hence, this is the critical path and duration = 104 days.



3

UNIT

Engineering Economy and Inventory Control

CONTENTS

- Part-1** : Methods of Depreciation, 3-2A to 3-15A
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PART- 1

Methods of Depreciation, Break-even Analysis, Techniques for Evaluation of Capital Investments, Financial Statements, Time-cost Trade-off, Resource Levelling.

CONCEPT OUTLINE**Techniques for Evaluation of Capital Investment :**

1. Payback period method.
2. Net present value.
3. Internal rate of return method.

Questions-Answers**Long Answer Type and Medium Answer Type Questions**

Que 3.1. What is depreciation ?

Answer

1. Depreciation is a measure of the wearing out, consumption or other loss of value of depreciable asset arising from use, effluxion of time or obsolescence through technology and market changes.
2. Depreciation is allocated so as to charge a fair proportion of the depreciable amount in each accounting period during the expected useful life of the asset.
3. Depreciation includes amortization of assets whose useful life is predetermined.
4. Depreciable assets are assets which :
 - i. Are expected to be used during more than one accounting period,
 - ii. Have a limited useful life, and
 - iii. Are held by an enterprise for use in the production or supply of goods and services, for rental to others or for administrative purposes and not for the purpose of sale in the ordinary course of business.

Que 3.2. What are the causes of depreciation ?

Answer

Causes of depreciation can be put under two categories :

a. Due to Physical Condition :

- i. **Wear and Tear :** As the machine is used, the machine parts wear. This is one of the causes of depreciation.
- ii. **Physical Decay :** Chemicals, cables, buildings etc, are affected by climate and atmosphere. Due to this they decay as time lapses.
- iii. **Accidental :** An accident may even occur to a new machine. This is one of the causes of depreciation. To overcome this, the machine should be insured.

b. Due to Functional Condition :

- i. **Inadequacy :** The equipment's efficiency reduces due to use and due to increase in demand for the product. Due to this the machine becomes inadequate to meet demand.
- ii. **Obsolescence :** Due to scientific advancements, large changes take place everyday. A new machine may be introduced into the market which is more efficient than the existing machine. Due to the new machine, the existing machine becomes outdated.

Que 3.3. Explain the methods of calculating depreciation.

Answer

Methods of calculating depreciation are as follows :

a. Straight Line Method :

1. This method assumes that depreciation occurs according to a straight line law.

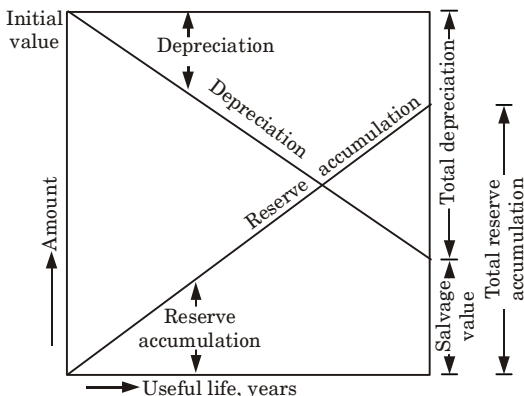


Fig. 3.3.1. Straight line depreciation.

2. Straight line annual depreciation reserve

$$= \frac{\text{Initial cost} - \text{Salvage value}}{\text{Number of years of useful life}}$$

- This method neglects the interest that the depreciation reserve would earn. It is very popular because of its simplicity.
- Fig. 3.3.1 illustrates this method.

b. Sinking Fund Method :

- This method is based on the fact that the annual depreciation reserve, when invested at compound interest, will accumulate to the difference between the initial cost and the salvage value at the end of the useful life of the equipment.
- Annual sinking fund depreciation reserve

$$= [\text{Initial cost} - \text{Salvage value}] \times \left[\frac{r}{(1+r)^n - 1} \right]$$

Where,

r = Interest rate and

n = Number of years.

- The sinking fund method is illustrated in Fig. 3.3.2.

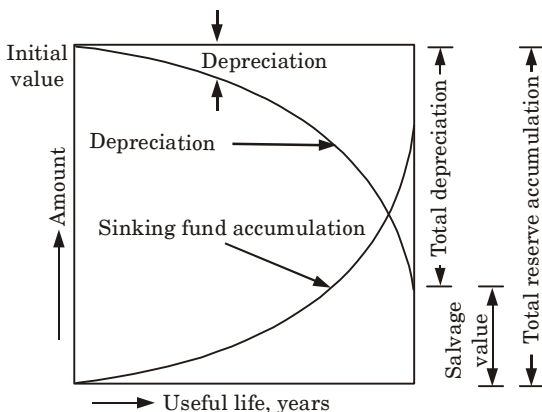


Fig. 3.3.2. Sinking fund depreciation.

c. Fixed Percentage Method :

- In this method, the depreciation reserve during any year is a fixed percentage (say x) of the remaining balance of initial investment minus total accumulated depreciation at the beginning of the year.
- This method is also known as declining balance method.
- Let C be the initial investment and n years be the life of the equipment.
- Annual depreciation during first year

$$= \frac{Cx}{100}$$

- Remaining balance at the beginning of second year

$$= C - \frac{Cx}{100} = C \left(1 - \frac{x}{100} \right)$$

6. Annual depreciation during second year

$$= C \left(1 - \frac{x}{100} \right) \frac{x}{100}$$

7. Remaining balance at the beginning of third year (*i.e.*, end of third year)

$$= C \left(1 - \frac{x}{100} \right)^2 - C \left(1 - \frac{x}{100} \right)^2 \frac{x}{100} = C \left(1 - \frac{x}{100} \right)^3$$

8. Remaining balance at the end of n years

$$= C \left(1 - \frac{x}{100} \right)^n$$

9. The remaining balance at the end of n years should be equal to salvage value S . Thus,

$$C \left(1 - \frac{x}{100} \right)^n = S$$

d. Insurance Policy Method :

1. This method covers the risk, if the machine becomes uneconomical to use before its estimated life.
2. In this method the machine is insured with the insurance company and premiums are paid on the insurance policy.
3. When the policy matures, the company gets back the money from the insurance company to replace the machine.

Que 3.4. A lathe was purchased for Rs. 90,000 on 1st January 1975, the erection and installation cost being Rs. 14,000. The lathe was replaced by new one on 31st December 1994. If the scrap value of the lathe was estimated as Rs 30,000, what should be the rate of depreciation and depreciation fund on 15th June 1984.

Answer

Given : Cost of lathe = Rs. 90,000, Erection and installation charges = Rs. 14,000, Scrap values = Rs. 30,000

To Find : Rate of depreciation and depreciation fund.

1. Initial cost of lathe,

$$C = (\text{Cost of lathe}) + (\text{Erection and installation charges})$$

$$= \text{Rs. } 90,000 + \text{Rs. } 14,000 = \text{Rs. } 1,04,000$$

2. Life of the lathe (N) = From 1st Jan. 1975 to 31st Dec. 1994

$$= 20 \text{ years}$$

3. Therefore rate of depreciation / year = $(C - S) / N$

$$= \text{Rs.}(1,04,000 - 30,000) / 20 = \text{Rs. } 3,700$$

4. Depreciation fund on 15 June 1984

$$\begin{aligned} &= 9 \text{ installments of depreciation i.e., from 1st Jan. } \\ &\quad 1975 \text{ to 15 June 1984 should be accumulated} \\ &= 9 \times 3,700 = \text{Rs. } 33,000 \end{aligned}$$

Que 3.5. Write a short note on break even analysis. What is the purpose of it ?

Answer

A. Break-even Analysis :

1. Break-even analysis, also known as cost-volume-profit analysis, is the study of inter-relationships among a firm's sales, costs and operating profit at various level of output.
2. It reveals the effect of fixed costs, variable costs, prices, sales mix, etc., on the profitability of a firm.
3. It is a simple method of presenting to management the effect of changes in volume on profit.

B. Purpose of Break-even Analysis :

1. To help in deciding profitable level of output, below which losses will occur.
2. To compute costs and revenues for all possible volumes of output to fix budgeted sales.
3. To decide the product mix and promotion mix.
4. To take plant expansion decisions.
5. To take equipment replacement decisions.

Que 3.6. What is break-even point ? What are the methods to determine break-even point ?

Answer

A. Break-even Point : It is concerned with finding the point at which revenues and costs are exactly equal. This point is known as break-even point.

B. Methods to Determine Break-even Point :

a. The Algebraic Method :

i. Break-even Point in Term of Physical Units :

1. Let,
 FC = Fixed cost
 VC = Variable cost per unit
 TVC = Total variable cost
 TC = Total costs
 TR = Total revenue i.e., total income

Q = Sales volume i.e., quantity sold

SP = Selling price per unit

2. We know that,

Total costs = Fixed cost + Variable cost

$$TC = FC + (VC \times Q)$$

3. Also, Total revenue = Selling price / unit \times Quantity sold

$$TR = SP \times Q$$

4. At break-even point (BEP),

$$TC = TR$$

$$FC + (VC \times Q) = SP \times Q$$

or $Q_{BEP} = FC / (SP - VC)$

$$\text{Break-even quantity} = \frac{\text{Fixed costs}}{(\text{Selling price / unit}) - (\text{Variable cost / unit})}$$

ii. Break-even Point in Term of Sales Value :

1. This method is suitable for a multi-product firm.

$$\text{Break-even sales (BEP in rupees)} = \frac{\text{Fixed costs}}{1 - \left(\frac{\text{Variable cost / unit}}{\text{Selling price / unit}} \right)}$$

$$\text{BEP in rupees} = \frac{FC}{1 - \left(\frac{VC}{SP} \right)}$$

b. The Graphical Method (Break-even Chart) :

1. Break-even chart is a graphical representation of the relationship between costs and revenue at a given time.
2. It is a graphic device to determine the break-even point and amount of loss or profit under varying conditions of output and costs.
3. A break-even chart is illustrated in Fig. 3.6.1.
4. In break-even chart, cost and revenue in rupees is represented on vertical axis, while output in quantity is represented on horizontal axis.
5. In Fig. 3.6.1, the fixed cost line is horizontal and parallel to the x -axis. It indicates that fixed costs remain unchanged for any volume.
6. The variable cost line is superimposed on the fixed cost line to show total costs.
7. The total sales revenue line is drawn as shown in Fig. 3.6.1. This line indicates sales income at various levels of output.

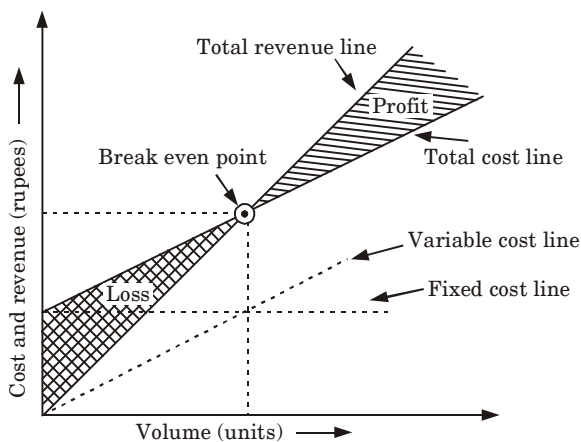


Fig. 3.6.1. Break-even chart.

8. The point at which the total revenue line intersects the total cost line is the break-even point.
9. The shaded area above the BEP marks profit to the firm whereas the shaded area below the BEP represents loss to the concern.

Que 3.7. Fixed costs are Rs. 40,000 per year, variable costs are Rs.50 per unit, and the selling price is Rs.90 each. Find the BEP.

Answer

Given : FC = Rs. 40,000; VC = Rs. 50; SP = Rs. 90

To Find : Break-event point (BEP).

1. We know that,

$$\begin{aligned} \text{BEP} &= \text{FC} / (\text{SP} - \text{VC}) \\ &= 40,000 / (90 - 50) = 1000 \text{ units} \end{aligned}$$

Que 3.8. Annual fixed costs at a small textile shop are Rs. 50,000 and variable costs are estimated at 50 % of the Rs. 40-per-unit selling price, (a) Find the BEP, (b) What profit (or loss) would result from a volume of 3,250 units ?

Answer

Given : FC = Rs. 50,000 ; SP = Rs. 40, VC = 50 % of SP = 20

1. Variable cost (VC) = $50/100 \times 40 = \text{Rs. } 20$
2. We know that, $\text{BEP} = \text{FC} / (\text{SP} - \text{VC}) = 50,000 / (40 - 20) = 2500$
3. Profit (or Loss) when $Q = 3250$ units

$$\text{Profit} = \text{Total revenue} - \text{Total cost}$$

$$\text{Total revenue} = \text{SP} \times Q = 40 \times 3250 = \text{Rs. } 1,30,000$$

$$\text{Total cost} = \text{FC} + \text{VC} \times Q = 50,000 + 20 \times 3250 = \text{Rs. } 1,15,000$$

$$\text{Profit} = 1,30,000 - 1,15,000 = \text{Rs. } 15,000$$

Que 3.9. What is payback period method ? Also write its advantages and disadvantages.

Answer

A. Payback Period Method :

1. The payback period is the minimum time taken by the system to recover the total investment costs.
2. The resulting calculation is the number of years that will be required for the measure to pay back the initial investment.
3. It is an evaluation technique for capital investment.
4. The pay back measures the number of years required for the cash inflows after taxes to pay back the original outlay required in project.
5. Payback period can be illustrated by cash flow diagrams (CFD) as shown in Fig. 3.9.1.

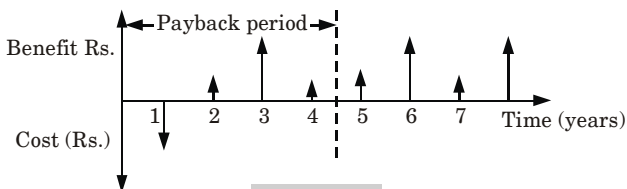


Fig. 3.9.1.

6. As indicated in the CFD, the large benefits occurring after the payback period are not considered in the payback evaluation.
7. Pay back (PB) is given by,

$$\text{PB} = \frac{\text{Initial Investment}}{\text{Net annual saving}}$$

B. Advantages of Payback Period Method :

1. Easy to understand.
2. Simple to calculate.
3. A simple way to screen relatively low cost measures based on payback period.

4. Easier of communication to a non-technical audience.

C. Disadvantages of Payback Period Method :

1. It does not measure correctly even the cash inflows within the payback period as it does not differentiate between projects in terms of timing or the magnitude of cash flows.
2. It does not take into consideration the entire life of the project during which cash flows are generated.
3. We cannot compare complex projects and measures where costs and savings vary in both magnitude and timing.
4. It does not account for benefits and costs after the equipment has been paid back, so it can disadvantages projects with long useful live (e.g. a high efficiency chiller with a 20 year life).

Que 3.10. Explain internal rate of return method.

Answer

1. Internal rate of return is defined as the discount rate (r) which equates the aggregate present value of the net cash inflows with the aggregate present value of cash outflows of project.
2. In other words, it is that rate which gives the project NPV of zero.
3. This method uses the discounted cash flow rate which equates the present value of the future cash inflows with the initial investment.
4. It is a type of discounted cash flow techniques which takes into account the time factor to value the future cash flows.
5. The internal rate of return is the discounted rate which makes the net present value equal to zero.
6. In net present value method, the discount rate is the required rate of return and cost of capital and its determinants are external to the proposal under study, while in IRR these are based on internal to the proposal.
7. Thus, while arriving at the required rate of return the cash flows (inflows and outflows) are not considered, but the IRR depends entirely on the initial outlay and the cash proceeds of the project. That is why it is referred as internal rate of return.
8. This method is also known as marginal efficiency of capital like the NPV method.

Que 3.11. Write down advantages and disadvantages of IRR method.

Answer

A. Advantages of IRR :

1. It is easier to understand.

- It takes into account the total cash inflows and outflows.
- It does not use the concept of required rate of return. It itself provides a rate of return.
- It is consistent with the overall objective of maximising shareholder's wealth.

B. Disadvantages of IRR :

- It involves tedious and complicated calculations.
- It produces multiple rates which can be confusing.
- In evaluating mutually exclusive proposals, the project with the highest IRR would be selected.
- In this method, it is assumed that all intermediate cash flows are reinvested at IRR.

Que 3.12. Describe net present value (NPV) method.

Answer

- Net present value (NPV) method also recognises the time value of money for evaluating investment proposals.
- It is similar to the IRR method except that a fixed discount rate is used for obtaining the present value of future cash inflows.
- The sum of the present values of the cash inflow less the cash outflow gives the net present value. If the net present value is positive, it means that the project is earning a rate of return higher than the discount rate.
- NPV may be described as the summation of the present values of all benefits in each year minus the summation of present values of all costs in each year.
- In this method, the discount is used to compare benefits and costs at a single point in time.
- Present value for project may be calculated as,

$$PV = \frac{CF}{(1+r)^t}$$

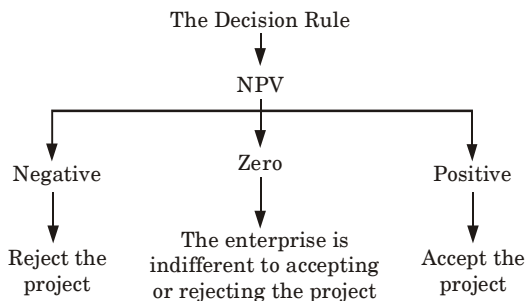
Where,

CF = Net cash flow,

r = Discount rate, and

t = Time of cash flow.

- The market price of the shares will be affected by the relative force of what the investors expect or what actual return is earned.
- The discount rate (r) that is used to convert benefits into present values is the minimum rate when the NPV is zero, the return on investment just equals the expected rate.
- If $NPV > 0$, the return would be higher than expected.

**Fig. 3.12.1.**

Que 3.13. Write down advantages and disadvantages of NPV method.

Answer

A. Advantages of NPV Method :

1. It explicitly recognises the time value of money.
2. It considers the total benefits arising out of proposal over its lifetime.
3. A changing discount rate can be built by altering the denominator.
4. It is very useful for the selection of mutually exclusive projects.
5. This method is instrumental in achieving the objective of financial management which is the maximization of the share holders.

B. Disadvantages of NPV Method :

1. It is difficult to understand as well as calculate.
2. The calculation of required rate of return is difficult because different discount rates give different present value.
3. It is an absolute measure.
4. This method may not give satisfactory results in case of two projects having different effective lives.

Que 3.14. Discuss concepts regarding financial statements.

Answer

1. A financial statement is an organised collection of data according to logical and consistent accounting procedures.
2. Its purpose is to convey an understanding of some financial aspects of a business firm.
3. The term financial statement generally refers to two basic statements :
 - a. The income statement, and

- b. The balance sheet.

A business may also prepare :

- c. A statement of retained earnings.
- d. A statement of changes in financial position in addition to the above two statement.

a. Income Statement :

- i. The income statement is generally considered to be the most useful of all financial statements.
- ii. It explains what has happened to a business as a result of operations between two balance sheet dates.

b. Balance Sheet :

- i. It is a statement of financial position of a business at a specified moment of time.
- ii. It represents all assets owned by the business at a particular moment of time and the claims of the owners and outsiders against those assets at that time.

c. Statement of Retained Earnings :

- i. The term retained earnings mean the accumulated excess of earnings over losses and dividends.
- ii. The balance shown by the income statement is transferred to the balance sheet through this statement after making necessary appropriations.
- iii. It is, thus, a connecting link between the balance sheet and the income statement.

d. Statement of Changes in Financial Position :

- i. The balance sheet shows the financial condition of the business at a particular moment of time while the income statement discloses the results of operations of business over a period of time.

Que 3.15. Explain nature of financial statements.

Answer

Following are the nature of financial statements :

a. Recorded Facts :

- 1. The term recorded facts mean facts which have been recorded in the accounting books.
- 2. Facts which have not been recorded in the financial books are not depicted in the financial statements.

b. Accounting Conventions :

- 1. Accounting conventions imply certain fundamental accounting principles which have been sanctified by long usage.

c. Personal Judgments :

1. Personal judgment has also an important bearing on a financial statement.
2. For example, the choice of selecting a method of depreciation lies on the accountant.
3. Similarly, the mode of amortization of fictitious assets also depends on the personal judgment of the accountant.

Que 3.16. Explain time-cost trade-off analysis.**Answer**

1. The objective of the time-cost trade-off analysis is to reduce the original project duration, determined from the critical path analysis, to meet a specific deadline, with the least cost.
2. In addition to that it might be necessary to finish the project in a specific time to :
 - i. Finish the project in a predefined deadline date.
 - ii. Recover early delays.
 - iii. Avoid liquidated damages.
 - iv. Free key resources early for other projects.
 - v. Avoid adverse weather conditions that might affect productivity.
 - vi. Receive an early completion-bonus.
 - vii. Improve project cash flow.

Que 3.17. Write short note on resource levelling.**Answer**

1. In the process of resource levelling, whenever the availability of resource becomes less than its maximum requirement, the only alternative is to delay the activity having larger float.
2. In case, two or more activities require the same amount of resources, the activity with minimum duration is chosen for resource allocation. Resource levelling is done if the restriction is on the availability of resources.
3. Steps involved in resource levelling :
 - i. Lower the peak requirement of the resources by staggering the resource-input on non-critical activities. If necessary, sub-critical and critical activities can also be tackled to bring peak demands below the specified levels. Thus, completion of work may be delayed due to resource constraints.

- ii. Either increase the duration of critical activities or place some of the concurrent activities in series to reduce the peak demands of the scarce resources. This will increase the duration of the project.
- iii. Rearrange the activities in descending order of the magnitude of the positive float, as resources can be conveniently diverted from the activities which possess large amount of float.

PART-2

Inventory Functions, Costs, Classifications, Deterministic Inventory Models, Perpetual and Periodic Inventory Control Systems, ABC Analysis, and VED Analysis.

CONCEPT OUTLINE

Deterministic Inventory Model : These are used to determine the optimal inventory of a single item when demand is mostly largely obscure. Under this model inventory is built up at constant rate to meet a determined or accepted demand.

Questions-Answers**Long Answer Type and Medium Answer Type Questions**

Que 3.18. Define inventory. Also gives its classification.

Answer

- A. Inventory :** Inventory is an accounting term that refers to goods that are in various stages of being made ready for sale, including :
- 1. Finished goods (that are available to be sold).
 - 2. Work-in-progress (meaning in the process of being made).
 - 3. Raw materials (to be used to produce more finished goods).
- B. Classification of Inventory :** Inventory can be broadly divided into two main categories :
- i. **Direct Inventories :** These are the inventories that are an integral part of the finished product. Important feature of direct inventories is that we can assign the stock to specific physical units. The different types of direct inventories are :
 - a. **Raw Materials :** These are goods which are to be used in the manufacturing process to produce final goods. They are the goods in their raw or natural form.

- b. Semi-Finished Goods :** These are also known as work-in-progress. Some further work has to be done before they can be sold. For example in a toy factory, toys that are molded but still have to be painted will be semi-finished goods.
 - c. Finished Goods :** These are fully completed goods ready for sale, but not yet sold.
- ii. Indirect Inventories :** Indirect inventories comprise of stock items that are necessary for the manufacturing of goods but are not a direct component of such goods.

Que 3.19. Define inventory control with its objectives and importance.

Answer

- A. Inventory Control :** It is the technique of maintaining the size of the inventory at some desired level keeping in view the best economic interests of an organization. It is the process of deciding what and how much of various items are to be kept in stock.
- B. Objectives of Inventory Control :**
1. To maintain the overall investment at the lowest level, consistent with operating requirements.
 2. To supply the product, raw material, sub-assemblies, semi-finished goods etc. to its users as per their requirements at right time and at right price.
 3. To keep inactive, waste, surplus, scrap and obsolete items at the minimum level.
 4. To minimize holding, replacement and shortage costs of inventories and maximize the efficiency in production and distribution.
 5. To protect against inflation since the prices of materials are constantly increasing.
 6. To avail quantity discounts on bulk purchases.
- C. Importance of Inventory Control :**
1. It improves the liquidity position of the firm by reducing unnecessary tying up of capital in excess inventories.
 2. It ensures smooth production operations by maintaining reasonable stocks of materials.
 3. It facilitates regular and timely supply to customers through adequate stocks of finished products.
 4. It protects the firm against variations in raw materials delivery time.
 5. It facilitates production scheduling, avoids shortage of materials and duplicate ordering.

6. It helps to minimise loss by obsolescence, deterioration, damage, etc.
7. It enables the firms to take advantage of price fluctuations through economic lot buying when prices are low.

Que 3.20. Mention advantages and disadvantages of inventory control. Also write down the function of inventory.

Answer

A. Advantages of the Inventory Control :

1. Provides cushion between work-centres thereby assures a smooth and efficient running of the organization.
2. Serves as a buffer stock in case of delayed deliveries by the suppliers.
3. Eliminates the possibility of duplicate ordering.
4. Helps in maintaining economy by absorbing some of the fluctuations when the demand for an item fluctuates or is seasonal.
5. Controls and minimizes accumulation and build-up of surplus stock, and eliminates the dead movable surplus stock as far as practicable.
6. Utilizes the benefits of price fluctuations.

B. Disadvantages of Inventory Control :

1. Inventories are often used wrongly as a substitute for management. For example, if there are large finished goods inventories, inaccurate sales forecasting by marketing department may never be apparent.
2. Similarly, a production foreman who has large-in-process inventories may be able to hide his poor planning since there is always something to manufacture.
3. Furthermore, inventory means unproductive 'tied-up' capital of the enterprise. The capital could be usefully utilized in other ventures as well.
4. With large inventory, there is always likelihood of obsolescence too.

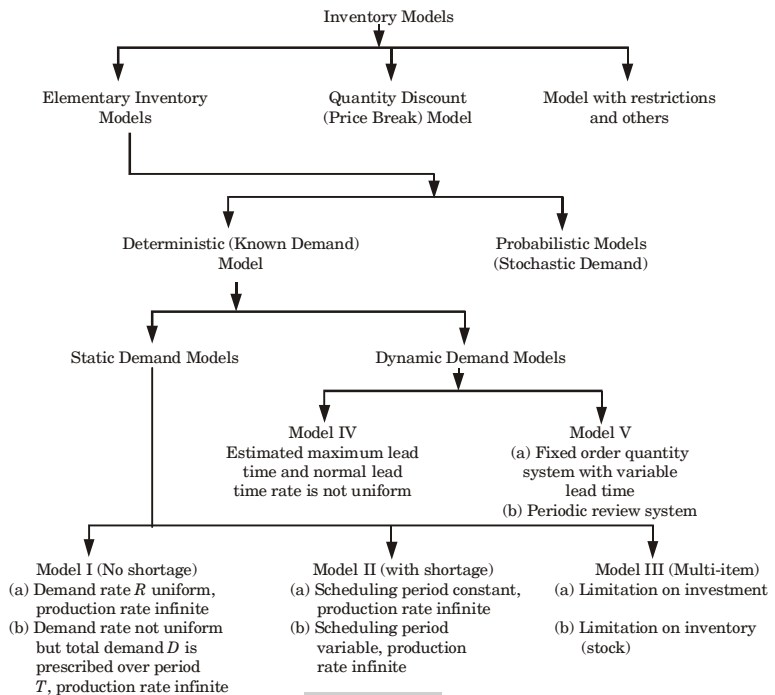
C. Inventory Function : Inventory functions are as follows :

1. To ensure in time deliveries/better customer relations.
2. To maintain smooth and efficient production flow.
3. To take advantage of quantity discounts.
4. To utilize to advantage price fluctuations.

Que 3.21. Enlist the various inventory models available. Explain any one of them in detail.

Answer

A. Various Inventory Models :

**Fig. 3.21.1.**

B. Single Period Inventory Method (Probabilistic Inventory Model) :

1. In most situations demand is probabilistic since only probability distribution of future demand, rather than the exact value of demand itself, is known.
2. The probability distribution of future demand is usually determined from the data collected from past experience.
3. In such situations we choose policies that minimize the expected costs rather than the actual costs.
4. Expected costs are obtained by multiplying the actual cost for a particular situation with the probability of occurrence of that situation and then either summing or integrating accordingly as the probability distribution is discrete or continuous.
5. Costly spare parts, perishable goods, seasonal items and fashion goods are examples of probabilistic models.
6. Replacement orders are either not possible or become abnormally expensive and uneconomical.

Que 3.22. What do you understand by EOQ ? How do you calculate EOQ ?

Answer

A. EOQ :

1. By the 'order quantity' we mean the quantity produced or procured during one production cycle.
2. When the size of order increases, the ordering costs (cost of purchasing, inspection etc.) will decrease whereas the inventory carrying costs (cost of storage, insurance, etc.) will increase.
3. Thus in the production process there are two opposite costs, one encourages the increase in the order size and the other discourages.
4. Economic order quantity (EOQ) is that size of order which minimizes total annual costs of carrying inventory and cost of ordering.
5. The two opposite costs can be shown graphically by plotting them against the order size.
6. It is evident from Fig. 3.22.1, that the minimum total cost occurs at the point where the ordering costs and inventory carrying costs are equal.

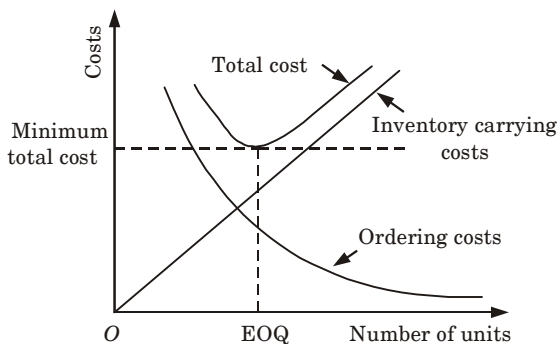


Fig. 3.22.1.

B. Formula for EOQ : Inventory costs are :

- Ordering cost = $\frac{\text{Total annual demand}}{\text{Quantity order each time}} \times \text{Ordering cost per order}$

$$= \frac{D}{Q} \times S$$
- Carrying cost = Average units in inventory \times Carrying cost per unit

$$= \frac{Q}{2} \times H$$

The total cost is minimum at a point where ordering cost equals carrying cost

$$\frac{D}{Q} \times S = \frac{Q}{2} \times H$$

Therefore, Economic order quantity EOQ is

$$EOQ = \sqrt{\frac{2DS}{H}}$$

EOQ is the economic order quantity (units).

D is demand per year,

S cost per order, and

H cost of holding per unit of inventory.

Que 3.23. Explain the following terms :

- a. **Lead time,**
- b. **Reorder point, and**
- c. **Buffer stock.**

Answer

a. Lead Time or Delivery Lag :

1. The time interval between placement of an order and receipt of goods against it is called lead time.
2. It is normally short in case of local supplier or off the shelf items and greater for made to order or out station supplier.
3. Lead time may not be a constant. For the same item and the same supplier it can vary from stage to stage.
4. Lead time may, therefore, be a stochastic variable. This complicates the problem of accumulating the forecasts of demand over the period encompassed by the lead time.

b. Reorder Point :

1. In a firm, there should be enough stock for each item so that customer's order can be reasonably met from this stock until replenishment.
2. This stock level is known as reorder level, has therefore, to be determined for each item.
3. It is determined by balancing the cost of maintaining these stocks and the disservice to the customer if his orders are not filled in time.
4. For example, if the lead time is 2 months, we will have to accumulate the next 2 months' forecasts in order to find the forecast lead time demand.

Reorder Level (ROL) = Lead time demand (LTD).

5. When the demand pattern is almost stationary and depicts no trend or seasonal variations,

Lead time demand = Lead time \times average demand ($LT \times R$)

- ∴ $ROL = \text{Lead time} \times \text{average demand}$
6. If the safety stock is provided, ROL is given by,
 $ROL = \text{Lead time demand} + \text{Safety stock}$
7. Further, if time T is required for reviewing the system, then

$$ROL = LTD + SS + \frac{RT}{2}$$

8. If there is provision of safety stock,
 maximum inventory = $Q + SS$

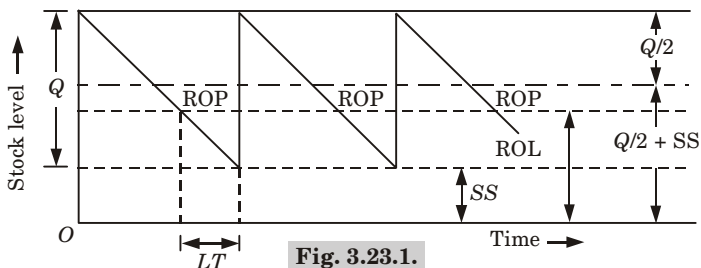


Fig. 3.23.1.

Minimum inventory = SS

$$\text{Average inventory} = \frac{SS + (Q + SS)}{2} = \frac{Q}{2} + SS$$

9. Fig. 3.23.1 represents an ideal inventory model wherein the actual demand is same as expected demand and there are no variations from the forecasts.
10. Here, the moment when stock level reaches the ROL, order of the fixed size Q ($= \text{EOQ}$) is placed, these points have been marked as reorder points (ROP).
11. As soon as the stock level reaches the safety stock, the supplies are received, the stock level, thereby, reaching the maximum level $Q + SS$.

c. Buffer Stock :

1. They are required as protection against the uncertainties of supply and demand.
2. A company may well know the average demand of an item that it needs, however, the actual demand may turn out to be quite different - it may well exceed the average value.
3. Similarly the average delivery period (lead time) may be known but due to some unforeseen reasons, the actual delivery period could be much more.
4. Such situations require extra stock of item to reduce the number of stock-outs or back-orders.
5. This extra stock in excess of the average demand during the lead time is called buffer stock (or safety stock or cushion stock).

Que 3.24. Write short notes on following :

- Ordering cost,
- Holding cost, and
- Inventory carrying cost.

Answer

a. Ordering Cost (C_o) :

- This is a cost associated with ordering of raw material for production purposes.
- Advertisements, consumption stationary and postage, telephone charges, telegrams, rent for space used by the purchasing department, travelling expenditures incurred, etc., constitute the ordering cost.

b. Holding Cost (C_h) :

- The cost associated with holding the goods in stock is known as holding cost.
- Holding cost is assumed to vary directly with the size of inventory as well as the time for which the item is held in stock.

c. Inventory Carrying Cost :

- These involve the rent of storage space or depreciation and interest even if the own space is used.

Que 3.25. A firm uses every year 12000 units of a raw material costing Rs. 1.25 per unit. Ordering cost is Rs. 15 per order and holding cost is 5 % per year of average inventory. Calculate :

- Economic order quantity (EOQ).
- Reorder point, if firm operates 300 days per year and lead time is 14 days and safety stock is 400 units.

Answer

Given : C_o = Rs. 15, D = 12000, Raw material cost = Rs. 1.25, C_h = 5% of average inventory, Lead time = 14 days, Safety stock = 400 units

- Economic order quantity, $EOQ = \sqrt{\frac{2C_o D}{C_h}}$

$$= \sqrt{\frac{2 \times 15 \times 12000}{\frac{5}{100} \times 1.25}} = 2400 \text{ units}$$
- Reorder level = Safety stock + Consumption during normal lead time

$$= 400 + 14 \times \frac{12000}{300} = 960 \text{ units}$$

Que 3.26. Write short on following

- a. **Perpetual inventory control system.**
- b. **Periodic inventory control system.**

Answer

a. Perpetual Inventory Control System :

1. In this method checking of inventory continues throughout the year and the material is checked at a point when it is minimum in stock so that there is no waste of time and verification is easy.
2. The responsibility of verification can given either to insider or to some outsider.
3. In this method work is not stopped for physical verification, as is the case with annual physical verification.

b. Periodic Inventory Control System :

1. The periodic system uses an occasional physical count to measure the level of inventory and the cost of goods sold. Merchandise purchases are recorded in the purchases account.
2. The inventory account and the cost of goods sold account are updated at the end of a set period-this could be once a month, once a quarter, or once a year.
3. Cost of goods sold is an important accounting metric, which, when subtracted from revenue, shows a company's gross margin.
4. Cost of goods sold under the periodic inventory system is calculated as follows :

$$\text{Beginning Balance of Inventory} + \text{Cost of Inventory Purchases} - \text{Cost of Ending Inventory} = \text{Cost of Goods Sold}$$

Que 3.27. What is ABC analysis ? What are its advantages and disadvantages ?

Answer

A. ABC analysis :

1. ABC analysis is a way of categorizing the material on the basis of the quantity of consumption and their relative values.
2. In ABC (Always Better Control) inventory management technique A category consists of high-priced inventory which may be less in number but are very expensive.
3. The items in B category are relatively lesser expensive inventory as compared to A category and the number of items in B category is moderate so control level is also moderate.

4. The C category consists of a high number of inventory items which require lesser investments so the control level is minimum.

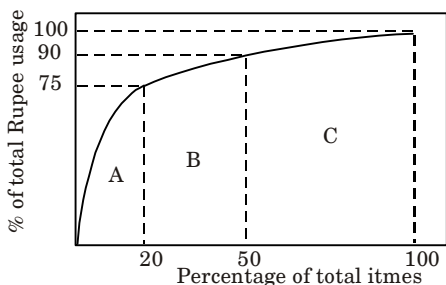


Fig. 3.27.1.

B. Advantages of ABC analysis :

- 1. Reduction in Investment :** Under ABC analysis, the materials from group 'A' are purchase in lower quantities as much as possible. With this, the effort to reduce the delivery period is also made. These in turn help to reduce the investment in material.
- 2. Strict Control :** Under ABC analysis, strict control can be exercised to the materials in group 'A' that have higher value.
- 3. Minimum Storage Cost :** Since, the material from group 'A' are purchase in lower quantities as much as possible, it reduce the storage cost as well.
- 4. Saving in Time :** Since a signification effort is made for management of the material from group 'A', it helps to save time as well.
- 5. Economy :** This method is economical, since equal time and labour is not needed for all types of materials.

C. Disadvantage of ABC Analysis :

1. ABC analysis will not be effective if the materials are not classified into the groups properly.
2. It is not suitable for the organization where the costs of materials do not vary significantly.
3. There is no scientific base for the classification of material under ABC analysis.
4. The classification of the materials into different groups may lead to extra cost. Hence, it may not be suitable for small organization.

Que 3.28. Write a short note on VED analysis.

Answer

1. VED analysis attempts to classify the items used into three broad categories namely, Vital, Essential, and Desirable.
2. The analysis classifies items on the basis of their criticality for the industry or company.
3. **Vital :** Vital category items are those items without which the production activities or any other activity of the company, would come to a halt, or at least be drastically affected.
4. **Essential :** Essential items are those items whose stock - out cost is very high for the company.
5. **Desirable :** Desirable items are those items whose stock-out or shortage causes only a minor disruption for a short duration in the production schedule. The cost incurred is very nominal.
6. VED analysis is very useful to categorize items of spare parts and components.

PART-3

Queuing Theory : Basis of Queuing Theory, Elements of Queuing Theory, Operating Characteristics of a Queuing System, Classification of Queuing Models.

Questions-Answers**Long Answer Type and Medium Answer Type Questions**

Que 3.29. What is a Queuing model ? Give basic structure of queuing system.

Answer

- A. Queuing Model :** A queuing model can be completely described by :
- a. The Input (or Arrival Pattern) :**
1. The input, describes the way in which the customers arrive and join the system.
 2. Generally, the customers arrive in a more or less random fashion which is not worth making the prediction.

3. Thus, the arrival pattern can be described in terms of probabilities and consequently the probability distribution for inter-arrival times or the distribution of number of customers arriving in unit time must be defined.

b. The Service Mechanism (or Service Pattern) :

1. It is specified when it is known how many customers can be served at a time, what the statistical distribution of service time is, and when service is available.
2. It is true in most situations that service time is a random variable with the same distribution for all arrivals, but cases occur where there are clearly two or more classes of customers (e.g., machines waiting for repairing) each with a different service time distribution.
3. Service time may be constant or a random variable.

c. The Queue Discipline :

1. The queue discipline is the rule determining the formation of the, queue the manner of the, customer's behaviour while waiting, and he manner in which they are chosen for service.
2. Properties of queuing system which are concerned with waiting times, in general, depend on queue discipline.

d. Customer's Behaviour : The customers generally behave in four ways :

- Balking :** A customer may leave the queue because the queue is too long and he has no time to wait, or there is not sufficient waiting space.
- Reneging :** This occurs when a waiting customer leaves the queue due to impatience.
- Priorities :** In certain applications, some customers are served before others regardless of their order of arrival. These customers have priority over others.
- Jockeying :** Customers may jockey from one waiting line to another. It may be seen that this occurs in the supermarket.

B. General Structure of Queuing System :

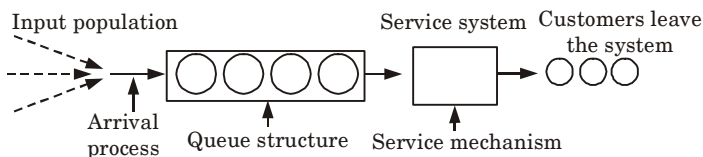


Fig. 3.31.1.

Que 3.30. Explain elements of queuing model.

Answer

Elements of queuing model are as follows :

a. Queue Discipline :

1. It is a rule according to which customers are selected for service when a queue has been formed.
2. The most common queue discipline is the “first come, first serve” (FCFS), or the “first in, first out” (FIFO) rule under which the customers are serviced in the strict order of their arrivals.
3. Other queue discipline include : “last in, first out” (LIFO) rule according to which the last arrival in the system is serviced first.
4. This discipline is practiced in most cargo handling situations where the last item loaded is removed first.
5. Besides these, other disciplines are : “selection for service in random order” (SIRO) rule according to which the arrivals are serviced randomly irrespective of their arrivals in the system, and a variety of priority schemes — according to which a customer’s service is done in preference over some other customer.

b. Input and Holding Times :

1. It represents the pattern in which customers arrive at the system.
2. Arrivals may also be represented by the inter-arrival time, which is the time period between two successive arrivals.
3. Arrivals may be separated by equal intervals of time, or unequal but definitely known intervals of time, or by unequal intervals of time whose probabilities are known, these are called random arrivals.
4. The rate at which customers arrive at the service station, that is the number of customers arriving per unit of time is called arrival rate.
5. The time elapsed from the commencement of service to its completion for a customer at a service facility is referred to the service time or holding time.

Que 3.31. Explain the characteristics of queuing system.

Answer

Characteristics of the queuing system are as follows :

- a. Queue Length (L_q) :** The average number of customer in the queue waiting to get service. This excludes the customers being served.
- b. System Length (L_s) :** The average number of customers in the system including those waiting as well as being served.

- c. **Waiting Time in the Queue (W_q)** : The average time for which a customer has to wait in the queue to get service.
- d. **Total Time in the System (W_s)** : The average total time spent by a customer in the system from the moment he arrives till leaves the system.
- e. **Utilization Factor (ρ)** : It is the proportion of time a server actually spends with the customer.

Que 3.32. A person repairing radios finds that time spent on radio sets has exponential distribution with mean 20 minutes. If the radios are repaired in the order in which they come in and their arrival is approximately Poisson with an average rate of 15 for 8 hours a day, what is repairman's expected idle time each day ? How many jobs are ahead of the average set just brought in ?

Answer

Given : $\lambda = \frac{15}{8 \times 60} = \frac{1}{32}$, $\mu = \frac{1}{20}$ units/minute.

To Find : i. Expected idle time.
ii. Average number of job in system

1. Number of jobs ahead of the set brought in = Average number of jobs in the system,

$$L_s = \frac{\lambda}{\mu - \lambda} = \frac{1/32}{1/20 - 1/32} = \frac{5}{3}$$

2. Number of hours for which the repairman remains busy in an 8-hour day,

$$= 8 \times \frac{\lambda}{\mu} = 8 \times \frac{1/32}{1/20} = 8 \times \frac{20}{32} = 5 \text{ hours.}$$

3. Therefore, time for which repairman remains idle in an 8-hour day,
= $8 - 5 = 3$ hours.

Que 3.33. Give classification of queuing models.

Answer

The various types of queuing models can be classified as follows :

A. Probabilistic Queuing Models :**a. Model I (Erlang Model) :**

1. This model is symbolically represented by $(M/M/1) : (FCFS/\infty/\infty)$. This represents Poisson arrival (exponential inter-arrival), Poisson departure (exponential service time), single server, first come-first serve service discipline, infinite number of customers allowed in the system and infinite population.
2. Since the Poisson and exponential distributions are related to each other, both of them are denoted by the symbol ' M ' due to Markovian property of exponential distribution.

b. Model II (General Erlang Model) :

1. Though this model is also represented by $(M/M/1) : (FCFS/\infty/\infty)$, it is a general queuing model in which the arrival and service rates depend upon the length of the queue.
2. Some person desiring service may not join the queue since it is too long, thus affecting the arrival rate.
3. Similarly, service rate is also affected by the length of the queue.

c. Model III :

1. This model is represented by $(M/M/1) : (SIRO/\infty/\infty)$.
2. It is essentially same as model I except that the service discipline is SIRO instead of FCFS.

d. Model IV :

1. This model is represented by $(M/M/1) : (FCFS/N/\infty)$.
2. In this model the capacity of the system is limited or finite, say N .
3. So the number of arrivals cannot exceed N .

e. Model V :

1. This model is represented by $(M/M/1) : (FCFS/N/M)$.
2. It is finite-population or limited source model.
3. In this model the probability of an arrival depends upon the number of potential customers available to enter the system.

f. Model VI :

1. This model is represented by $(M/M/C) : (FCFS/\infty/\infty)$.
2. This is same as model I except that there are C service channels working in parallel.

g. Model VII :

1. This model is represented by $(M/E_k/1) : (FCFS/\infty/\infty)$.
2. In this model instead of exponential service time, there is Erlang service time with k phases.

h. Model VIII :

1. This model is represented by $(M/M/1) : (GD/M/N)$, where $M \leq N$.
2. It represents machine repair problem with a single repairman. N is the total numbers of machines out of which M are broken down and forming a queue.

i. Model IX :

1. This model is represented by $(M/M/C) : (GD/M/N)$, $M \leq N$.
2. It is same as model VIII except that there are C repairmen, $C < N$.

j. Model X : This is called power supply model.

B. Deterministic Model :**a. Model XI :**

1. This model is represented by $(D/D/1) : (FCFS/\infty/\infty)$.
2. In this model inter-arrival time as well as service time are fixed and known with certainty.
3. The model is, therefore, called deterministic model.

C. Mixed Queuing Model :**a. Model XII :**

1. This model is represented by $(M/D/1) : (FCFS/\infty/\infty)$.
2. Here, arrival rate is Poisson distributed while the service rate is deterministic or constant.

Que 3.34. What are the important assumptions of queuing models ?

Answer

Important assumptions of queuing models are as follows :

1. The customers arrive for service at a single service facility at random according to Poisson distribution with mean arrival rate λ or equivalently, the inter-arrival times follow exponential distribution.
2. The service time has exponential distribution with mean service rate μ .

3. The service discipline followed is first come, first served.
4. The waiting space available for customers in the queue is infinite.
5. The calling source (population) has infinite size.
6. The elapsed time since the start of the queue is sufficiently long so that the system has attained a steady state or stable state.
7. The mean arrival rate λ is less than the mean service rate μ .



4

UNIT

Work System Design

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PART- 1

*Taylor's Scientific Management, Gilbreth's Contributions,
Work Study, Method Study, Micro-motion Study,
Principles of Motion Economy.*

CONCEPT OUTLINE**Techniques of Motion Study :**

1. Therblig analysis.
2. Micro-motion study.

Questions-Answers**Long Answer Type and Medium Answer Type Questions**

Que 4.1. Write a short note on Taylor's scientific management.

Answer

1. The primary emphasis of scientific management was on planning, standardizing and improving human effort at the operative level in order to maximize output with minimum input.
2. Taylor believed that managing should be based on objective assessment of facts, on measurement and not on guess work.
3. Scientific management is the result of applying scientific knowledge and the scientific methods to the various aspects of management and the problems that arise from them.
4. Taylor thought that by maximizing the productive efficiency of each worker, scientific management would also maximize the earnings of the employees and employers.
5. Scientific management could be summarized as :
 - i. Science, not rule of thumb,
 - ii. Harmony, not discord,
 - iii. Cooperation, not individualism,
 - iv. Maximum output, in place of restricted output, and
 - v. The development of each worker to his greatest efficiency and prosperity.

Que 4.2. Explain Gilbreth's contribution.

Answer

1. Gilbreth defined motion study “as the science of eliminating wastefulness resulting from unnecessary, ill directed and inefficient motions”.
2. According to Gilbreth the purpose of motion study was to discover and establish the scheme of least waste methods of labour. He also evolved the principles of motion economy.
3. While concentrating on the economical motions for doing a job, Gilbreth felt the necessity of charting the activities to be analysed, because a chart could provide the overall picture as well as the importance of everything involved.
4. Gilbreth identified Therbligs as the fundamental motions involved in doing an activity.
5. He developed microchronometer, cyclegraph, chronocyclegraph, and flow diagram.

Que 4.3. What is Therblig ? Explain.**Answer**

- a. A therblig is the name for one of a set of fundamental motions required for a worker to perform a manual operation or task.
- b. The set consists of 18 elements, each describing a standardized activity. These are listed below :

1. Search,	2. Find,
3. Select,	4. Grasp,
5. Hold,	6. Position,
7. Assemble,	8. Use,
9. Disassemble,	10. Inspect,
11. Transport loaded,	12. Transport unloaded,
13. Pre position for next operation,	14. Release load,
15. Unavoidable delay,	16. Avoidable delay,
17. Plan, and	18. Rest to overcome fatigue,
- c. The therblig is used in the study of motion economy in the workplace.
- d. A workplace task is analyzed by recording each of the therblig units for a process, with the results used for optimization of manual labour by eliminating unneeded movement.
- e. A single operation can consist of many therblig.

Que 4.4. What is work study ? Write the steps in work study.

Answer

- A. Work Study :** It is a technique used to examine the activities done by human being and investigate those factors that affect the accuracy and efficiency of the workers. Work study helps to complete a particular work or job in the best possible way.
- B. Steps of Work Study :**
1. It selects the jobs which are to be studied.
 2. It examines critically the recorded facts which are already done.
 3. It records from direct observations all the matters which are happened.
 4. It defines new method.
 5. It also installs the new method.
 6. It also maintains the new standard.
 7. It develops most economic and appropriate methods.
 8. It measures the work content in the method that is selected and compute a standard time.

Que 4.5. What are the objectives of work study ? Write its advantages also.

Answer

- A. Objectives of Work Study :**
1. Improved working process and standardized procedures.
 2. Better plant layout and clean, planned environment and working conditions.
 3. Less fatigue to the operator.
 4. Improved quality product.
 5. Effective utilization of men, material and machinery.
 6. Efficient and faster material handling.
 7. Health hazard is reduced.
- B. Advantages of Work Study :**
1. Uniform and improved production flow.
 2. Higher productive efficiency.
 3. Reduced manufacturing costs.
 4. Fast and accurate delivery dates.
 5. Better employee-employers relations.
 6. Better service to customers.

Que 4.6. Define method study. What are its objective and steps ?

Answer

- A. Method Study :** Method study is the systematic recording and critical examination of existing and proposed ways of doing work, as a means of developing and applying easier and more effective methods and reducing costs. It is a systematic procedure to analyze the work to eliminate unnecessary operations.
- B. Objective of Method Study :**
1. It improves the proper utilization of manpower, machine and materials.
 2. It also improves the factory layout, work place, etc.
 3. It also improves the process and procedure.
 4. It develops better physical working environment.
 5. It reduces undesirable fatigue.
- C. Steps of Method Study :** The steps of method study are :
1. At first select the proper work which is to be studied.
 2. Record all the facts of existing method.
 3. Examine the facts very critically.
 4. Develop the most practical, economic, and effective method.
 5. Install the method and the same should be maintained.

Que 4.7. What is micro-motion study ? What is the purpose of it ?

Answer

- A. Micro-motion Study :**
1. Micro-motion study is defined as the study of fundamental elements of an operation.
 2. It is carried out with the help of a high speed movie camera in order to eliminate the unnecessary motions involved in the operation and balancing the necessary motion.
 3. The elements or motions are finite subdivisions of the work cycle.
- B. Purpose of Micro-motion Study :**
1. Aid in studying the activities of two or more persons on group work.
 2. Aid studying the relationship of the activities of the operator and the machine.
 3. Obtain motion - time data for time standards.
 4. Serves as a permanent record of method and time of activities of the operator and the machine.
 5. Research in the field of motion and time study.

Que 4.8. Write down the advantages and applications of micro-motion study ?

Answer

A. Advantages of Micro-motion Study :

1. Films keep a permanent record of motion study.
2. Films can easily reveal the difference between the present method and the proposed method.
3. Films can be shown to a large work force at the same time and at any desired speed.
4. Operations can be filmed more accurately and conveniently than by stop watch time study.
5. Study of activities can be made with minimum disturbance to the operators.

B. Application of Micro-motion Study :

1. It is used to improve especially short and highly repetitive work cycle methods.
2. It can be used as an aid in training the operators.
3. It can be used in the design and development of special machinery.
4. For collecting motion - time data for synthetic time standards.
5. It enables in the study of man-machine and group activities.
6. It is accurate and positive techniques for carrying out research in the field of work study.

Que 4.9. What are the principles of motion economy ?

Answer

1. The principles of motion economy developed by Gilbreth envisage the correct application of theories behind motion elements to achieve synchronization of human body movements, best layout of workplaces and the optimum design of equipment and tools and time conservation.
2. There are four basic principles of motion economy which are listed below :
 - i. Principles related to human body.
 - ii. Principles related to the arrangement of work place.
 - iii. Principles related to design of tools and equipment.

Que 4.10. Explain the principles of motion economy related to the use of human body.

Answer

Principles of motion economy related to the use of human body are as follows :

1. The two hands should begin as well as complete their motions at the same time.
2. The two hands should not be idle at the same time except during rest periods.
3. Motions of the arms should be made in opposite and symmetrical directions and should be made simultaneously.
4. Hand and body motion should be confined to the lowest classifications with which it is possible to perform the work satisfactory.
5. Momentum should be employed to assist the worker wherever possible, and it should be reduced to a minimum it must be overcome by muscular effort.
6. Smooth continuous curved motions of the hands are preferable to straight line motions involving sudden and sharp changes in direction.
7. Ballistic movements are faster, easier and more accurate than restricted or controlled movements.
8. Work should be arranged to permit easy and natural rhythm wherever possible.
9. Eye fixations should be as few and as close together as possible.

Que 4.11. Explain the principles of motion economy related to the arrangement of work place.

Answer

Principles of motion economy related to the arrangement of work place are :

1. There should be a definite and fixed place for all tools and materials.
2. Tools, materials, and control should be located close to the point of use.
3. Gravity feed bins and containers should be used to deliver material close to the point of use.
4. Drop deliveries should be used wherever possible.
5. Materials and tools should be located to permit the best sequence of motions.
6. Provision should be made for adequate conditions for seeing. Good illumination is the first requirement for satisfactory visual perception.
7. The height of the work place and the chair should preferably be arranged so that alternate sitting and standing at work are easily possible.

8. A chair of the type and height to permit good posture should be provided for every worker.

Que 4.12. Explain the principles of motion economy related to the design of tools and equipments.

Answer

Principles of motion economy related to the design of tools and equipments are :

1. The hands should be relieved of all work that can be done more advantageously by a jig, a fixture, or a foot-operated device.
2. Two or more tools should be combined wherever possible.
3. Tools and materials should be repositioned whenever possible.
4. Where each finger performs some specific movement, such as in typewriting the load should be distributed in accordance with the inherent capacities of the fingers.
5. Levers, crossbars, and hand wheels should be located in such positions that the operator can manipulate them with the least change in body position and with the greatest mechanical advantage.

PART-2

Work Measurement : Time Study, Work Sampling, Standard Data, Predetermined Motion Time System (PMTS), Ergonomics, Job Evaluation, Merit Rating, Incentive Schemes and Wage Administration.

CONCEPT OUTLINE

Time Study : It may be defined as “the art of observing and recording the time required to do each detailed element of an industrial operation.” Time study standardized the time taken by an average worker to perform these operations.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 4.13. Define work measurement. Write its objectives.

Answer**A. Work Measurement :**

1. Work measurement is concerned with elimination of ineffective time and establishment of time standards for a job.
2. Work measurement is a technique to establish the time for a qualified worker to carry out a specified job at a definite level of performance.

B. Objectives of Work Measurement :

1. To reduce or eliminate ineffective time.
2. To set standard time for a job.
3. To set standard data for future use.
4. To complete standardization of given jobs.
5. To improve methods of doing jobs.

Que 4.14. What is the role of time study in production ?

Answer

1. When a customer wants to purchase some products, then he usually compares the prices with those of similar products, which are being manufactured by other producers.
2. Therefore, to give competitive quotations, estimation of accurate labour cost is very essential as it has got large effect on the price.
3. Secondly, whenever a customer contracts for the purchase of certain products then he desires that the products should reach to him at a promised date which is only possible when manufacturer is aware of the time to be taken by the product during manufacture.
4. Therefore, to find the correct manufacturing time for product, time study is performed.
5. Time study also helps in analysis of work and standardization of methods.

Que 4.15. Define stopwatch methods of work measurement ?

Explain its importance.

Answer**A. Stopwatch Method of Work Measurement :**

- i. **Definition :** Stopwatch time study measures how long it takes an average worker to complete a task at a normal pace.
- ii. **Methods of Timing using Stopwatch :** There are two methods of timing using a stopwatch. They are :
 - a. **Fly Back Method :**
 1. Here the stopwatch is started at the beginning of the first element. At the end of the element the reading is noted in the study sheet.

2. At the same time, the stopwatch hand is snapped back to zero. This is done by pressing down the knob, immediately the knob is released.
3. The hand starts moving from zero for timing the next element. Thus the timing for each element found is called observed time.

b. Continuous Method :

1. Here the stopwatch is started at the beginning of the first element. The watch runs continuously throughout the study.
2. At the end of each element the watch readings are recorded on the study sheet. The time for each element is calculated by successive subtraction.
3. The final reading of the stopwatch gives the total time known as observed time.

B. Importance : The importance and uses of stopwatch time study can be stated as under :

1. Determining schedules and planning work.
2. Determining standard costs and as an aid in preparing budgets.
3. Estimating the costs of a product before manufacturing it. Such information is of value in preparing bids and determining selling price.
4. Determining machine effectiveness, the number of machines which one person can operate, and as an aid in balancing assembly lines and work done on a conveyor.
5. Determining time standards to be used as a basis for labour cost control.
6. Helps to know the labour productivity, labour efficiency, labour performance and overall time required to perform the task.
7. Helps to improve the process of operation.

Que 4.16. Explain the steps required in making time study.

Answer

Following are the steps required in making time study :

Step 1 : Define objective of the study. This involves statement of the use of the result, the precision desired, and the required level of confidence in the estimated time standards.

Step 2 : Verify that the standard method and conditions exist for the operation and the operator is properly trained.

Step 3 : Select operator to be studied if there are more than one operator doing the same task.

Step 4 : Record information about the standard method, operation, operator, product, equipment, and conditions on the time study observation sheet.

Step 5 : Divide the operation into reasonably small elements, and record them on the time study observation sheet.

Step 6 : Time the operator for each of the elements. Record the data for a few numbers of cycles on the time study observation sheet. Use the data to estimate the total number of observations to be taken.

Step 7 : Collect and record the data of required number of cycles by timing and rating the operator.

Step 8 : Calculate the representative watch time for each element of operation. Multiply it by the rating factor to get normal time.

Normal time = Observed time \times Rating factor

Calculate the normal time for the whole operation by adding the normal time of its various elements.

Step 9 : Determine allowances for fatigue and various delays.

Step 10 : Determine standard time of operation.

Standard time = Normal time + Allowances

Que 4.17. What is work sampling ? Give the steps of work sampling.

Answer

A. Work Sampling :

i. Definition :

1. Work sampling (also sometimes called ratio delay study) is a technique of getting facts about utilization of machines or human beings through a large number of instantaneous observations taken at random time intervals.
 2. The ratio of observations of a given activity to the total observations approximates the percentage of time that the process is in that state of activity.
- ii. Use of Work Sampling for Standard Time Determination :** Work sampling can be very useful for establishing time standards on both direct and indirect labour jobs.

B. Steps of Work Sampling : Steps of work sampling are as follows :

Step 1 : Define the problem.

1. Describe the job for which the standard time is to be determined.
2. Unambiguously state what are the activities of job that would entitle him to be in 'working' state and any activity other than those would entitle him to be in "not working" state.

Step 2 : Design the sampling plan :

1. Estimate satisfactory number of observations to be made.
2. Decide on the period of study, for example, two days, one week, etc.
3. Prepare detailed plan for taking the observations.

Step 3 : Contact the persons concerned and take them in confidence regarding conduct of the study.

Step 4 : Make the observations at the pre-decided random times about the working / not working state of the operator. When operator is in working state, determine his performance rating. Record both on the observation sheet.

Step 5 : Obtain and record other information. This includes operator's starting time and quitting time of the day and total number of parts of acceptable quality produced during the day.

Step 6 : Calculate the standard time per piece.

Que 4.18. Write advantages and limitations of work sampling.

Answer

A. Advantages of Work Sampling :

1. It is cheaper technique than time study and production study.
2. Only one analyst is sufficient to do work sampling study of many jobs.
3. Observers need not require much training, controlled.
4. It is preferred by the operator.

B. Limitations of Work Sampling :

1. It will prove to be costly if it is used for a single operator or job and also when operators or jobs are spread over a large area.
2. This study gives an average result but no information regarding individual activities is given.
3. It is not as fine and minute as time study.
4. Operators may knowingly make the study biased by anticipating observation.

Que 4.19. Define standard data. What is the use of standard data ?

Answer

A. Standard Data :

1. It is a catalogue of normal time values for different elements of jobs or for minute movements involved in different jobs.
2. This catalogue is prepared by compiling the timings of a number of standard elements.

B. Uses of Standard Data :

1. To estimate standard time for new jobs of repetitive or non-repetitive nature, quickly and economically.
2. For estimating production times for pricing inquiries made by customers or for quotation purposes.
3. In job design, process planning and scheduling.

4. To measure productive labour for cost checks.
5. For balancing production operations.
6. As a realistic basis for incentive plans.
7. For constructing time formulae.
8. To calculate the number of automatic machines which an operator can handle effectively.
9. To find percentage efficiency of manual operations.
10. In machine shops where similar jobs are manufactured in different sizes.

Que 4.20. Write the procedure of developing the standard data.

Answer

Following are the steps involved in developing standard data :

1. Break the jobs into elements. There are three types of elements, namely constant elements, variable elements and machine elements.
2. Obtain or conduct time studies for wide varieties of jobs/job families under different sets of parameters and conditions.
3. Summarize time studies using a summary form.
4. Separate constant elements from variable elements.
5. Using statistical methods calculate the average standard time for constant elements.
6. Compile the standard data, and
7. Test the data for its correctness and accuracy.

Que 4.21. Write a short note on predetermined motion time system (PMTS).

Answer

1. It may be defined as a work measurement technique to build up time for manual work making use of predetermined elemental motion times.
2. Manual operations are divided into fundamental elements and time to accomplish each element is tabulated.
3. To get the standard time of any operation, the operation is divided into fundamental elements.
4. The time of performance for each element is taken directly from the tables. Therefore, before doing any operation its standard time could be known.
5. Predetermined times are tabulated values of normal times to complete basic motions. Unlike synthesis time which is limited within organizations, these elemental times have got universal applicability.

Que 4.22. What are the advantages and disadvantages of PMTS ?

Write its application also.

Answer

A. Advantages of PMTS :

1. It eliminates inaccuracies associated with stop watch time study.
2. It is superior to stop watch time study when applied to short cycle highly repetitive operations.
3. Time standard for a job can be arrived at without going to the place of work.
4. Unlike stop watch study, no rating factor is employed.
5. PMTS data, since it is the result of very large number of observations, is more reliable and accurate as compared to stop watch time study data.

B. Disadvantages of PMTS :

1. PMTS can deal only with manual motions of an operation.
2. All categories of motions have not been considered while collecting PMTS data.

C. Applications of PMTS :

1. Machining work,
2. Maintenance work,
3. Assembly jobs,
4. Servicing, and
5. Office work.

Que 4.23. Define ergonomics. What its objectives ? Write its application also.

Answer

A. Ergonomics : Ergonomics or its American equivalent 'Human engineering' may be defined as the scientific study of the relationship between man and his working environments.

B. Objectives of Ergonomics :

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

C. Applications of Ergonomics :

1. Working environments,
2. The workplace, and
3. Other areas *i.e.*, studies related to fatigue.

Que 4.24. What do you mean by job evaluation ? What are its objectives ?

Answer**A. Job Evaluation :**

1. Job evaluation is a systematic process of evaluating different jobs of an organization.
2. Depending upon the characteristics and requirements of a job, job evaluation determines its relative worth and attaches a value to it.
3. These relative values of jobs assist in deciding wage rates and salaries for different jobs.

B. Objectives of Job Evaluation :

1. Decides the relative values of different jobs in an organization.
2. Helps to formulate an appropriate and uniform wage structure.
3. Clarifies the responsibility and authority connected with each job.
4. Provides a basis for recruitment, selection, training, promotion and transfer of the employees.
5. Improves employer-employee relationship.

Que 4.25. Explain the method of job evaluation.

Answer

Following are the various method of job evaluation :

- a. Ranking Method :** The different jobs, depending upon their requirements, responsibilities involved and their importance to the organization, are ranked, graded or placed from top to bottom.
- b. Classification or Grading Method :** Jobs are classified or graded in groups or levels of equal skill, difficulty, responsibility, importance and other requirements. It may be a production job, a sales job or an office job, each job family can be broken into a number of grades.
- c. Factor Comparison Method :** The method employs a five factor scale for analysis, comparing and evaluating different jobs. The five factors are skill, mental effort, physical effort, responsibility and working conditions.

Que 4.26. Define merit rating. What are its objectives ?

Answer

- A. Merit Rating :** It is a systematic and orderly approach to assess the relative worth of an employee working in an organization in terms of his job performance, integrity, leadership, intelligence, behaviour, etc.
- B. Objectives of Merit Rating :**
1. Merit rating provides a record of the worth of employees; they, therefore, can be put on the most appropriate jobs depending upon their capabilities.
 2. Merit rating unfolds the limitations of an employee and thus helps in employee improvement.
 3. Merit rating records form a basis for :
 - i. Wage-increase,
 - ii. Promotion,
 - iii. Special assignments,
 - iv. Training,
 - v. Transfer, and
 - vi. Discharge.

Que 4.27. Write a short note on wage administration.

Answer

1. Wage refers to the remuneration paid to the employees employed in an organization.
2. Wage is one of the important factors which affect the labour management relationship.
3. Workers are very much concerned about their wage structure, because it affects their standard of living.
4. Main components of wage are as follows :
 - a. Basic Wage :** It represents the money value equivalent of the worthiness of the job. It does not include any allowances. It depends upon the nature of job and the type of business.
 - b. Dearness Allowance :** This allowance is given to compensate the increase in cost of living due to rise in prices of different commodities.
 - c. Bonus :** Bonus is the extra amount paid to the employees from the profit earned by the company.
 - d. Overtime Payment :** This is the extra wage to be paid to workers when they work beyond normal working hours. Overtime wages will be double the normal wages.

Que 4.28. Define incentives. What are the types of incentives ?

Answer

- A. Incentives :** Incentive is a reward given to a worker for his efficiency and hard work. It encourages and motivates a worker to produce more and better.
- B. Classification of Incentives :** Incentives may be classified as follows :
- a. Direct Incentive :** This is the reward given a individual worker depending upon his own performance.
 - b. Indirect Incentive :** This is the reward given to a group of workers based on the group's performance.
 - c. Financial Incentive :** This refers to the direct monetary payment for the extra effort.
 - d. Non Financial Incentive :** This includes the following :
 - i. Better working condition.
 - ii. Promotion chances.
 - iii. Job security.

Que 4.29. Write down the objective of incentive scheme.

Answer

Following are the objective of incentive scheme :

- 1. The incentive scheme should be profitable to both workers and management.
- 2. It should help increasing production and there by lower the related costs.
- 3. It should reward workers in proportion to their output, and thus high up their morale.
- 4. The characteristics of an incentive scheme should be such that an able worker is in a position to earn sufficient amount of money to raise his standard of living.
- 5. An incentive scheme should provide recognition to a worker for his good contribution.

PART-3

Principles of Product Design, Tolerance Design, Quality and Cost Consideration, Product Life Cycle.

CONCEPT OUTLINE

Product Design : Product design is the process designers uses to blend user needs with business goals to help brands make consistently successful products. Product designers work to optimize the user experience in the solutions they make for their users-and help their brands by making products sustainable for longer-term business needs.

Questions-Answers**Long Answer Type and Medium Answer Type Questions**

Que 4.30. What are the various steps of product design ?

Answer

Various steps of product design are as follows :

Step 1 : Idea Development : Someone thinks of a need and a product/service design to satisfy customers, marketing, engineering, competitors, benchmarking, reverse engineering.

Step 2 : Product Screening : Every business needs a formal/structured evaluation process to fit with facility and labour skills, size of market, contribution margin, break-even analysis, return on sales.

Step 3 : Preliminary Design and Testing : Technical specifications are developed, prototypes built, testing starts.

Step 4 : Final Design : Final design based on test results, facility, equipment, material, and labour skills defined, suppliers identified.

Que 4.31. Write a short note on tolerance design.

Answer

1. Tolerance design refers to the selection of specifications for individual components using formal optimization.
2. Specifications might relate to the acceptable length of a shaft, for example, or the acceptable resistance of a specific resistor in a printed circuit board.
3. Choices about the specifications are important in part because conforming component parts can cause the entire engineered system to fail to conform to specifications.

- Also, sometimes the specification limits may be needlessly tight requiring expensive manufacturing equipment that does not benefit the customer.

Que 4.32. Explain the basic principle and concept of achieving quality in design.

Answer

- The quality of design of a product is concerned with the tightness of the specifications for manufacture of the product.
- A good quality of design must ensure consistent performance over its stipulated life span stated as rated output, efficiency, overload capacity for specified service.
- It must consider the possible modes of failure due to stress, wear, distortion, corrosion and vibrations etc.
- However, product design and development is a continuous process which results into evaluation of a product based on assessed user needs, their feedback after use and development in technology at a given point of time in a given environment.

- Factors affecting the quality of design are as follows :

a. Types of Customer in the Market :

- This includes the “market survey” for consuming habits of people, prices they are willing to pay, the choice of design of the product.
- But for capital goods, the decision is usually governed by such considerations as intended life, environmental conditions, reliability, maintainability etc.

b. Profit Consideration :

- From company's point of view, profit is more important.
- It is not necessary that the company should manufacture 100 % quality products.
- Profit can be maximized by producing products in different grades to suit different types of customers.

c. Environmental Conditions :

- This also plays an important role in deciding quality of design. *e.g.*, a car radiator designed for use in equatorial regions should be designed for increased ambient temperature.
- A well designed bus body known for its good performance abroad, has failed to withstand both, road conditions and loading pattern in our country.

d. Special Requirements of the Product :

- Generally, greater for strength, fatigue resistance, life, interchangeability of manufactured items closer tolerance should be given for better quality goods.

Que 4.33. Describe the typical product life cycle. Explain the various stages of the cycle.

Answer

A. Product Life Cycle :

1. The concept of a product life cycle has occupied a prominent place in the marketing literature, both as a forecasting tool and a guideline for corporate marketing strategy.

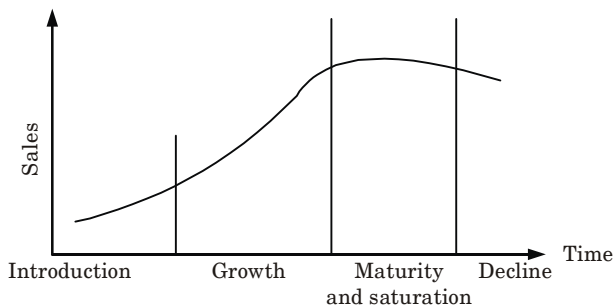


Fig. 4.33.1. Product life cycle.

2. In its simplest form, it serves as a descriptive model of the stages of market acceptance of a product.
3. It can thus be considered the “supply” view of the diffusion model which conceives a product reaching the customer through a ‘diffusion’ process.

B. Various Stages of Cycle :

a. Introduction Stage :

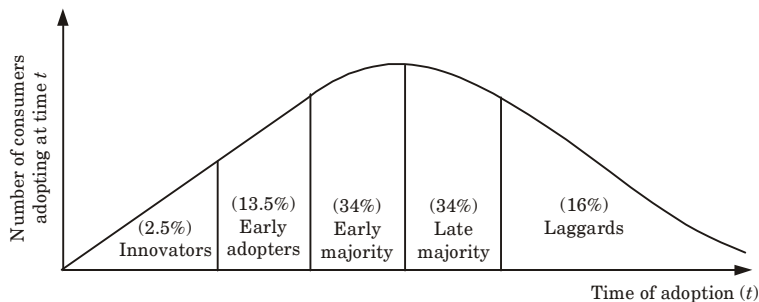


Fig. 4.33.2. New product adoption categories.

1. The introductory sales of a product are believed to be relatively slow, even after its technical problems have been ironed out, due to a number of marketing forces and consumer behaviour factors.

2. The major marketing obstacle to rapid introduction of a product is often distribution.
3. Retail outlets are often reluctant to introduce new products, and many prefer to wait until a track record has been established before including them in their stock.

b. Growth Stage :

1. The growth stage begins when demand for the new product starts increasing rapidly.
2. In the case of frequently-purchased products, innovators move from the trial to repeat purchase if they are satisfied with the product though innovators may influence others by word-of-mouth, which is often considered the most effective mode of communication.
3. The greatest importance at this stage is the entry of competitors who, through their advertising and promotional efforts, increase the total demand for the product.

c. Maturity Stage :

1. The maturity or saturation stage occurs when distribution has reached its planned or unplanned peak, and the percentage of total population that is ever going to buy the product has been reached.
2. Volume reflecting the number of customers, quantity purchased, and frequency of purchase is stable in the maturity stage.
3. This is the stage in which it becomes difficult to maintain effective distribution, and price competition is quite common.

d. Decline Stage :

1. Changes in competitive activities, consumer preferences, product technology, and other environmental forces tend to lead to the decline of most mature products.
2. If the decline is for a product (as distinct from a brand), producers may discontinue some brands and even withdraw from the given product category.
3. The typical reason for a product decline is the entry of new products, coupled with decreased consumer interest in the specific product.

PART-4

Standardization, Simplification, Diversification, Value Engineering and Analysis, and Concurrent Engineering.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 4.34. Define standardization. Write down the applications of standardization.

Answer

- A. Standardization :** It is temporary crystallization of the best acceptable solution to a recurring problem, formulated in a scientific and systematic fashion by pooling the knowledge of all those who are concerned with the problem and is subjected to review and revision by common consent, and one should comply with it.
- B. Applications of Standardization :**
1. Finished products, e.g., cars and televisions.
 2. Subassemblies and components, e.g., automobile gearboxes and auto-electric bulbs.
 3. Material standardization, e.g., both of direct materials (plain carbon and alloy steels, arc welding electrode core wires, etc.) and indirect materials (such as oils and greases).
 4. Production equipment standardization, e.g., that of machine tools, presses, welding equipments, etc.

Que 4.35. What are the advantages and disadvantages of standardization ?

Answer

- A. Advantages of Standardization :**
1. Rationalize different varieties of products.
 2. Decrease the volume of products in the store and also the manufacturer cost.
 3. Improve the management and design.
 4. Speed up the management of orders.
 5. Facilitate the exportation and marketing of products.
 6. Simplify purchasing management.
- B. Disadvantages of Standardization :**
1. Reduction in choice because of reduced variety and consequent loss of business or custom.
 2. Changes in public taste seriously affect a company producing only standardized product range.
 3. It becomes difficult to introduce new models because of less flexible (existing) production facilities and due to the high cost of specialized production equipment.

Que 4.36. What do you mean by simplification ? Write its advantages.

Answer

A. Simplification :

1. Simplification is the process of reducing the variety of products manufactured (known as variety reduction).
2. It is concerned with the reduction of product range, assemblies, parts, materials and design.
3. A manufacturer may reduce the number of different types of radio sets from a dozen to three or four to simplify his range.

B. Advantages of Simplification :

1. Since simplification reduces variety, volume of remaining products may be increased.
2. It provides quick delivery and better after-sales service.
3. It reduces inventory and thus results in better inventory control.
4. Generally speaking, simplification implies fewer parts and fewer the parts, the lower the production costs.
5. Simplification reduces price of a product and improves product quality.

Que 4.37. What is diversification ? What are the reasons for diversification ?

Answer

A. Diversification :

1. Diversification means additions of new products or introduction to established product into new market.
2. This tends to increase complexity of the methods of manufacturing, because, sometimes consumers like to have variety in type, size colour and quality of product being manufactured.
3. This adds to the cost characteristic of the production which is of varied nature.
4. Diversification adds to the classes of consumers served, by developing new technical knowledge.

B. Reasons for Diversification : Following are the reasons for diversification :

a. Survival :

1. To offset declining or vanishing markets.

2. To offset obsolete facilities.
3. To offset declining profit margins.
4. To compensate for technological obsolescence.

b. Stability :

1. To offset seasonal slumps.
2. To offset cyclical fluctuations.
3. To provide balance between high margin and low margin products.
4. To maintain market share.

c. Productive Utilization of Resources :

1. To utilize waste or by-products.
2. To make use of basic raw materials
3. To utilize excess productive capacity.
4. To make use of innovations from internal technical research.

d. Adaptation to Change in Customer Needs :

1. To meet the demands of diversified dealers.
2. To meet the specific requests of important groups of customers.
3. To improve performance of existing products through adding accessories.

Que 4.38. Explain value engineering.

Answer

1. Value Engineering (VE) is concerned with new products. It is applied during product development.
2. The focus is on reducing costs, improving function or both, by way of teamwork-based product evaluation and analysis.
3. This takes place before any capital is invested in tooling, plant or equipment.
4. Value engineering should be considered as crucial activity late on in the product development process and is certainly a wise commercial investment, with regard to the time it takes.
5. It is strongly recommended you build value engineering into your new product development process, to make it more robust and for sound commercial reasons.

Que 4.39. Write a short note on value analysis.

Answer

1. Value analysis (VA) is concerned with existing products. It involves a current product being analyzed and evaluated by a team, to reduce costs, improve product function or both.

2. Value analysis exercises use a plan which step-by-step, methodically evaluates the product in a range of areas.
3. These include costs, function, alternative components and design aspects such as ease of manufacture and assembly.
4. A significant part of value analysis is a technique called functional analysis, where the product is broken down and reviewed as a number of assemblies.
5. The function is identified and defined for each product assembly. Costs are also assigned to each one. This is assisted by designing and viewing products as assemblies.
6. As with value engineering, value analysis is a group activity that involves brain storming improvements and alternatives to improve the value of the product, particular to the customer.

Que 4.40. What is the role of value engineering in evaluating design to improve quality ?

Answer

1. Value analysis is an organized method of cost reduction of a product by attacking its basic design.
2. Its approach is similar to that of method study.
3. The difference is that where method study concentrates on improving the method of manufacture, the value analysis questions the product design itself, with a view of evolving a cheaper design system that can perform the intended function.
4. In the search of cheaper design, quality is not sacrificed; rather it often leads to improvement in quality.

Que 4.41. What do you understand by the term concurrent engineering ?

Answer

1. Concurrent engineering is also known as simultaneous or parallel engineering.
2. Concurrent engineering is a variable approach in which simultaneous design of a product and all its related processes in a manufacturing system are taken into consideration and also ensure the product matches the required product's structural with functional requirements.
3. Concurrent engineering also associates the manufacturing implications.
4. Concurrent engineering is used to launch a product early. It reduces the production lead-time.
5. It also manages the parallel processing to reduce the delay and waste.
6. All the experts from all corresponding departments such as design,

production and marketing are involved in the complete development process.

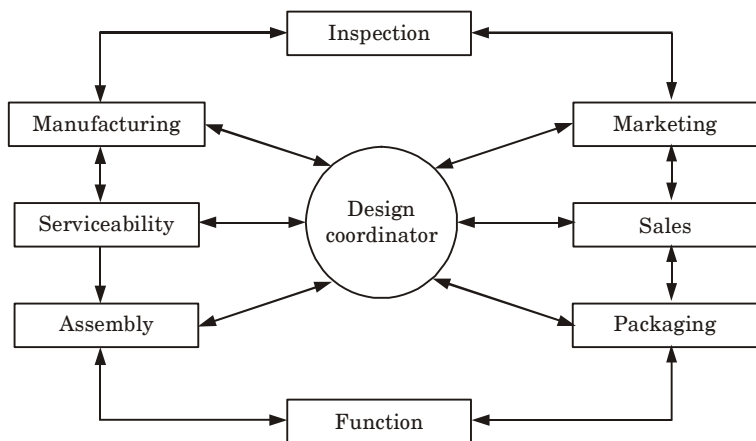


Fig. 4.41.1. Concept of concurrent engineering.

Que 4.42. Write the objectives and advantages of a concurrent engineering. Also, discuss its limitations.

Answer

A. Objectives of Concurrent Engineering :

1. Decreased product development time.
2. Improved profitability.
3. Better control on design and manufacturing costs.
4. Greater competitiveness.
5. Improved product quality.
6. Close integration between departments.

B. Advantages of Concurrent Engineering :

1. It reduces the production lead time.
2. It increases the profitability.
3. It also increases the competition among the manufacturing plants.
4. It improves the quality value of company and its product.
5. It also encourages the team spirit among all departments.

C. Limitations of Concurrent Engineering :

1. If specification of product lacks, it needs to implement an excessive amount of modification.

2. On manufacturing issues of the product there is a lack of attention.
3. Due to late changes in design leads to expensive changes to tooling and other equipments.



5

UNIT

Operational Analysis

CONTENTS

- Part-1** : Formulation of LPP, 5-2A to 5-11A
Graphical Solution of LPP,
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PART- 1

Formulation of LPP, Graphical Solution of LPP, Simplex Method.

Questions-Answers**Long Answer Type and Medium Answer Type Questions**

Que 5.1. What do you mean by linear programming problem (LPP) ? Describe the basic elements in a LPP.

Answer**A. Linear Programming Problem (LPP) :**

1. Linear programming deals with the optimization (maximization or minimization) of a function of variables known as objective functions. It is subject to a set of linear equalities and / or inequalities known as constraints.
2. Linear programming is a mathematical technique, which involves the allocation of limited resources in an optimal manner, on the basis of a given criterion of optimality.
3. Linear programming is a technique for determining an optimum schedule of interdependent activities in view of the available resources.
4. The term programming means scheduling. Programming is just another word for planning and refers to the process of determining a particular plan of action from amongst several alternatives.
5. The word linear indicates that all relationships involved in a particular problem are linear.

B. Basic Elements in LPP :

- a. **Decision Variables and their Relationship :** The decision variables refer to candidates that are competing with one another for sharing the given limited resources.
- b. **Well-defined Objective Function :** A linear programming problem must have a clearly defined objective function to optimize which may be either to maximize contribution by utilizing available resources or it may be to produce at the lowest possible cost by using a limited amount of productive factors.
- c. **Presence of Constraints or Restrictions :** There must be limitations or constraints on the use of limited resources which are to be allocated among various competitive activities.

- d. Alternative Courses of Action :** There must be alternative courses of action, for example, it must be possible to make a selection between various combinations.
- e. Non-Negative Restriction :** All decision variables must assume non-negative values as negative values of physical quantities is an impossible situation.
In other words, $x_1 \geq 0, x_2 \geq 0, \dots, x_n \geq 0$.

Que 5.2. How will you formulate a LPP mathematically ?

Answer

The procedure for mathematical formulation of a linear programming problem consists of the following major steps :

Step 1 : Study the given situation to find the key decisions to be made.

Step 2 : Identify the variables involved and designate them by symbols.

$$x_j \ (j = 1, 2, \dots)$$

Step 3 : State the feasible alternatives which generally are : $x_j \geq 0$, for all j .

Step 4 : Identify the constraints in the problem and express them as linear inequalities or equations, LHS of which are linear functions of the decision variables.

Step 5 : Identify the objective function and express it as a linear function of the decision variables.

Que 5.3. XYZ factory manufactures two articles A and B. To manufacture the article A, a certain machine has to be worked for 1.5 hours and in addition a craftsman has to work for 2 hours. To manufacture the article B, the machine has to be worked for 2.5 hours and in addition the craftsman has to work for 1.5 hours. In a week the factory can avail of 80 hours of machine time and 70 hours of craftsman's time. The profit on each article A is Rs. 50 and that on each article B is Rs. 40. If all the articles produce can be sold away, find how many of each kind should be produced to earn the maximum profit per week. Formulate the problem as LP model.

Answer

1. The data of the given problem can be summarized in the following tabular form :

Decision Variable	Article	Machine Time	Craftsman's Time	Profit Per Unit
x_1	A	1.5	2	Rs. 50
x_2	B	2.5	1.5	Rs. 40
Hours available (per week)		80 maximum	70 maximum	

- Let x_1 and x_2 be the number of articles A and articles B to be manufactured, respectively.
- Since total profit consists of profit derived from selling type A articles at Rs. 50 each plus the profit derived from selling type B articles at Rs. 40 each.
- Thus, $50 x_1$ is the profit earned by selling type A articles and $40 x_2$ is the corresponding profit by selling type B articles.
- As the factory wants to achieve the greatest possible profit (say Z), it can be stated algebraically by writing profit equation as :

$$\text{Maximize } Z = 50 x_1 + 40 x_2$$

- These are limitations or restrictions placed on availability or resources and can be constructed as follows :

- Machine time for article A + Machine time for article B

$$\leq \text{Available time on machine}$$

$$\text{i.e., } 1.5 x_1 + 2.5 x_2 \leq 80$$

- Craftsman time for article A + Craftsman time for article B

$$\leq \text{Available craftsman time}$$

$$\text{i.e., } 2 x_1 + 1.5 x_2 \leq 70$$

- Because, it is not possible to produce negative number of articles, we also include non-negative constraints,

$$x_1 \geq 0, \quad x_2 \geq 0$$

- Thus the appropriate mathematical formulation of the given problem as LP model is as shown below :

$$\text{Maximize (total profit) } Z = 50 x_1 + 40 x_2$$

Subject to the linear constraints

$$1.5 x_1 + 2.5 x_2 \leq 80$$

$$2 x_1 + 1.5 x_2 \leq 70$$

$$x_1, x_2 \geq 0$$

Que 5.4.

How will you solve a LPP using graphical method ?

Answer

Simple linear programming problems of two decision variable can be easily solved by using graphical method as follows :

Step 1 : Consider each inequality constraint as equation.

Step 2 : Plot each equation on the graph, as each one will geometrically represent a straight line.

Step 3 : Shade the feasible region. Every point on the line will satisfy the equation of the line. If the inequality constraint corresponding to the line is \leq , then the region below the line lying in the first quadrant is shaded. The points lying in common region will satisfy all the constraints simultaneously. The common region thus obtain is called a feasible region.

Step 4 : Choose the convenient value of Z (say $= 0$) and plot the objective function line.

Step 5 : Pull the objective function line upto the extreme points of the feasible region. In the maximization case, this line will stop farthest from the origin and passing through at least one corner of the feasible region.

Step 6 : Read the coordinates of the extreme points selected in step 5, and find the maximum or minimum value of Z .

Que 5.5.

What are the limitations of graphical method for solving LPP ?

Answer

Limitations of graphical method for solving LPP are as follows :

1. Linear programming works only with the variables that are linear.
2. It deals with the problem having single objective.
3. Non-linear function cannot be solved over here.
4. Impossibility of solving some problem which has more than two variables in graphical method.

Que 5.6.

Maximize $Z = 3x_1 - x_2$

Subject to $2x_1 + x_2 \leq 2,$
 $x_1 + 3x_2 \geq 3,$
 $x_2 \leq 4,$
 $x_1, x_2 \geq 0.$

Answer

1. Max $Z = 3x_1 - x_2$
 Subject to $2x_1 + x_2 \leq 2$

$$x_1 + 3x_2 \geq 3,$$

$$x_2 \leq 4,$$

$$x_1, x_2 \geq 0$$

2. On removing inequality sign,

$$2x_1 + x_2 = 2$$

$$x_1 + 3x_2 = 3,$$

$$x_2 = 4$$

3. After plotting the values on graph, ABC is the feasible region as shown in Fig. 5.6.1.

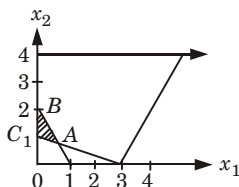


Fig. 5.6.1.

4. Value of maximum on extreme corners on triangle ABC ,

$$A \left(\frac{3}{5}, \frac{4}{5} \right), Z = 1$$

$$B(0, 2), Z = -2$$

$$C(0, 1), Z = -1$$

5. Hence, the maximum value of $\text{Max } Z = 1$ at point $A \left(\frac{3}{5}, \frac{4}{5} \right)$.

Que 5.7.

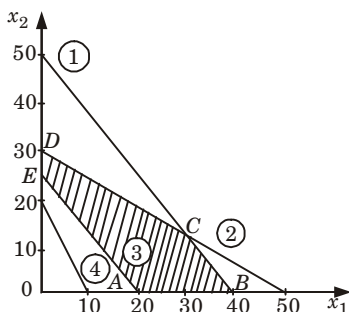
The manager of an oil refinery is to decide upon the optimal mix of two possible blending processes, of which the inputs and outputs per production run are as follows :

Process	Input		Output	
	Crude A	Crude B	Gasoline X	Gasoline Y
1	5	3	5	8
2	4	5	4	4

The maximum amount available of crude A and B is 200 units and 150 units respectively. Markets requirements show that at least 100 units of gasoline X and 80 units of gasoline Y must be produced. The profits per production run from process 1 and 2 are Rs. 3 and Rs. 4 respectively. Formulate the problem as a linear programming problem and solve the problem by graphical method.

Answer

- Let the quantity for blending process 1 is x_1
The quantity for blending process 2 is x_2
- Then constraints : $5x_1 + 4x_2 \leq 200$
 $3x_1 + 5x_2 \leq 150$
 $5x_1 + 4x_2 \geq 100$
 $8x_1 + 4x_2 \geq 80$
 $\text{Max } Z = 3x_1 + 4x_2$
- Now considering equality sign,
 $5x_1 + 4x_2 = 200$
 $3x_1 + 5x_2 = 150$
 $5x_1 + 4x_2 = 100$
 $8x_1 + 4x_2 = 80$
- On plotting the graph as shown in Fig. 5.7.1 $ABCDEA$ is a feasible region,

**Fig. 5.7.1.**

- The optimum value of objective function occurs at one of the extreme (corner) points of the feasible region. The coordinates of extreme points are :
 $A = (20, 0), B = (40, 0),$
 $C = \left(\frac{400}{13}, \frac{150}{13} \right), D = (0, 30), \text{ and } E = (0, 25).$
- Now, we compute the Z value corresponding to the extreme points :

Extreme Points	Coordinates (x_1, x_2)	Max $Z = 3x_1 + 4x_2$
A	(20, 0)	60
B	(40, 0)	120
C	(400/13, 150/13)	138.46 (Maximum)
D	(0, 30)	120
E	(0, 25)	100

7. Therefore max $Z = 138.46$ at $x_1 = \frac{400}{13}$, $x_2 = \frac{150}{13}$
8. Hence, to maximize the profit per production, the manager should run 400/13 blending of process 1 and 150/13 blending of process 2 per production.

Que 5.9. Define the following terms :

- Slack variable,
- Surplus variable,
- Optimal solution,
- Feasible solution,
- Basic solution,
- Basic feasible solution, and
- Degenerate solution.

Answer

- Slack Variable :** A variable added to the left hand side of a less than or equal to constraint, to convert the constraint into an equality is called a slack variable.
- Surplus Variable :** A variable subtracted from the left hand side of the greater than or equal to constraint, to convert the constraint into an equality is called a surplus variable.
- Optimal Solution :** Any basic feasible solution which optimized (minimizes or maximizes) the objective function of a general LP problem is called an optimal basic feasible solution to the general LP problem.
- Feasible Solution :** Any solution that also satisfies the non negative restrictions of the general LP problem is called a feasible solution.
- Basic Solution :** For a set of m simultaneous equations in n unknowns ($n > m$), a solution obtained by setting $(n - m)$ of the variables equal to zero and solving the remaining m equations in n unknowns is called a basic solution. The variables $(n - m)$ are called non-basic variables and remaining m variables are called basic variables and constitute a basic solution.
- Basic Feasible Solution :** A feasible solution to a general LP problem which is also basic solution is called a basic feasible solution.

- g. Degenerate Solution :** A basic solution to the system of equations is called degenerate solution if one or more of the basic variables become equal to zero.

Que 5.10. Write an algorithm to solve a linear programming problem using simplex method.

Answer

For the solution of any LPP by using simplex method, the steps for the computation of an optimum solution are as follows :

Step 1 : Check whether the objective function of the given LPP is to be maximized by using the result, Minimum $Z = -$ Maximum $(-Z)$.

Step 2 : Check whether all b_i ($i = 1, 2, \dots, m$) are non negative. If any one of b_i is negative then multiply the corresponding inequation of the constraints by -1 , so as to get all b_i ($i = 1, 2, \dots, m$) non negative.

Step 3 : Convert all the inequations of the constraints into equations by introducing slack and/or surplus variable in the constraints.

Step 4 : Obtain an initial basic feasible solution to the problem in the form $x_B = B^{-1}b$ and put it in the first column of the simple table.

Step 5 : Compute the net evaluations $Z_j - C_j$ ($j = 1, 2, \dots, n$) by using the relation $Z_j - C_j = C_B y_j - C_j$.

Examine the sign of $Z_j - C_j$:

1. If all $(Z_j - C_j) \geq 0$ then the initial basic feasible solution X_B is an optimum basic feasible solution.
2. If at least one $(Z_j - C_j) < 0$, proceed on to the next step.

Step 6 : If there are more than one negative $Z_j - C_j$, then choose the most negative of them. Let it be $Z_r - C_r$ for some $j = r$.

1. If all $Y_{ir} \leq 0$ ($i = 1, 2, \dots, m$) then there is an unbounded solution to the given problem.
2. If at least one $Y_{ir} > 0$ ($i = 1, 2, \dots, m$) then the corresponding vector Y_r enters the basis Y_B .

Step 7 : Compute the ratios $\left\{ \frac{X_{Bi}}{Y_{ir}}, Y_{ir} > 0, i = 1, 2, \dots, m \right\}$ and

choose the minimum of them. Let the minimum of these ratios be X_{Bk}/Y_{kr} . Then the vector Y_k will leave the basis Y_B . The common element Y_{kr} , which is in the k^{th} row and the r^{th} column is known as the leading element (or pivotal element) of the table.

Step 8 : Convert the leading element to unity by dividing its row by the leading element itself and all other elements in its column to zeros by making use of the relations :

$$\hat{Y}_{ij} = \hat{Y}_{ij} - \frac{Y_{kj}}{Y_{kr}} Y_{ir} \quad i = 1, 2, \dots, m+1; i \neq k$$

$$\text{and} \quad \hat{Y}_{kj} = \frac{Y_{kj}}{Y_{kr}} \quad j = 0, 1, 2, \dots, n$$

Step 9: Go to step 5 and repeat the computational procedure, either an optimum solution is obtained or there is an indication of an unbounded solution.

Que 5.11. Solve :

$$\text{Max. } Z = x_1 + x_2 + x_3$$

Subject to :

$$4x_1 + 5x_2 + 3x_3 \leq 15$$

$$10x_1 + 7x_2 + x_3 \leq 12$$

$$\text{and} \quad x_1, x_2, x_3 \geq 0$$

Answer

1. Given : Max.

$$Z = x_1 + x_2 + x_3$$

Subject to

$$4x_1 + 5x_2 + 3x_3 \leq 15$$

$$10x_1 + 7x_2 + x_3 \leq 12$$

$$\text{and } x_1, x_2, x_3 \geq 0$$

2. After introducing slack variable, the constraint equations become,

$$4x_1 + 5x_2 + 3x_3 + S_1 = 15$$

$$10x_1 + 7x_2 + x_3 + S_2 = 12$$

Max.

$$Z = x_1 + x_2 + x_3 + 0S_1 + 0S_2$$

$$x_1, x_2, x_3, S_1, S_2 \geq 0$$

3. First Iteration :

		C_j	1	1	1	1	1	
Basis Variables	C_B	X_B	x_1	x_2	x_3	S_1	S_2	Min. Ratio X_B/x_j
S_1	0	15	4	5	3	1	0	$15/3 = 5 \leftarrow$
S_2	0	12	10	7	1	0	1	$12/1 = 12$
$Z_j = \sum C_B a_{ij}$		0	0	0	0	0	0	$\leftarrow \Delta_j$
		$Z_j - C_j$	-1	-1	-1 ↑	0	0	

4. Second Iteration :

		C_j	1	1	1	1	1	
Basis Variables	C_B	X_B	x_1	x_2	x_3	S_1	S_2	Min. Ratio X_B/x_j
x_3	1	5	4/3	5/3	1	1/3	0	
S_2	0	12	26/3	16/3	0	-1/3	1	
$Z_j = \sum C_B a_{ij}$			1/3	3/2	0	1/3	0	

5. Since all $\Delta_j \geq 0$, therefore the optimum solution is obtain by the solution given $x_1 = 0$, $x_2 = 0$, $x_3 = 5$
 Max $Z = 5$ is optimal.

PART-2

*Sensitivity Analysis, Degeneracy and Unbound Solutions
 Transportation and Assignment Models.*

Questions-Answers**Long Answer Type and Medium Answer Type Questions**

Que 5.12. Define sensitivity analysis. Mention advantages of sensitivity analysis.

Answer**A. Sensitivity Analysis :**

- The investigation that deals with changes in the optimal solution due to changes in the parameters (a_{ij} , b_i and c_j) is called sensitivity analysis or post optimality analysis.
- The objective of sensitivity analysis is to reduce the additional computational effort considerably which arise in solving a new problem.
- The changes in the linear programming problem which are usually studied by sensitivity analysis include :
 - Changes in objective function coefficients, c_j 's, i.e., profit (or cost) per unit associated with decision variables.
 - Changes in b_i values (or right hand side constants of the constraints), i.e., available resources.

- iii. Changes in the coefficients of variables on the left hand side of the constraints, a_{ij} 's, i.e., consumption of resources per unit of decision variables x_{ij} .
- iv. Structural changes due to the addition and subtraction of some variables.
- v. Structural changes due to the addition and subtraction of some linear constraints. In general, these changes may result in one of the following three cases :

Case 1 : The optimal solution remains unchanged, i.e., the basis variables and their values remain essentially unchanged.

Case 2 : The basis variables remain the same, but their values are changed.

Case 3 : The basis solution changes completely.

B. Advantages of Sensitivity Analysis :

1. It compels the decision maker to identify the variables which affect the cash flow forecasts. This helps him in understanding the investment project in totality.
2. It indicates the critical variables for which additional information may be obtained. The decision maker can consider actions which may help in strengthening the weak spots in the project.
3. It helps to expose inappropriate forecasts and thus guides the decision maker to concentrate on relevant variables.

Que 5.13. What do you mean by degeneracy in a LPP ? How will you resolve degeneracy ?

Answer

- A. Degeneracy in LPP :** At the stage of improving the solution during simplex procedure, minimum ratio X_B/x_k ($x_k > 0$) is determined in the last. But, sometimes this ratio may not be unique i.e., the key element is not uniquely determined at the very first iteration, the variables value (one or more) in the X_B column become equal to zero, this causes the problem of degeneracy.
- B. Method to Resolve Degeneracy :** The following systematic procedure can be utilized to avoid cycling due to degeneracy in LPP :
- Step 1 :** First pick up the rows for which the minimum non negative ratio is same (tied). To be definite, suppose such rows are first, third, etc.
- Step 2 :** Now rearrange the columns of the usual simplex table so that columns forming the original unit matrix come first in proper order.
- Step 3 :** Then find the minimum of the ratio :

$$\left[\frac{\text{Elements of first columns of unit matrix}}{\text{Corresponding elements of key column}} \right]$$

Only for the rows for which minimum ratio was not unique. That is, for the rows first, third, etc., as picked up in step 1.

1. If this minimum is attained for third row (say), then this row will determine the key element by intersecting the key column.
2. If this minimum is also not unique, then go to next step.

Step 4 : Now compute the minimum of the ratio :

$$\left[\frac{\text{Elements of second columns of unit matrix}}{\text{Corresponding elements of key column}} \right]$$

Only for the rows for which minimum ratio was not unique in step 3.

1. If this minimum ratio is unique for the first row (say), then this row will determine the key element by intersecting the key columns.
2. If this minimum is still not unique then go to next step.

Step 5 : Next compute the minimum of the ratio :

$$\left[\frac{\text{Elements of third columns of unit matrix}}{\text{Corresponding elements of key column}} \right]$$

For the rows for which minimum ratio was not unique in step 4.

1. If this minimum ratio is unique for the third row (say), then this row will determine the key element by intersecting the key column.
2. If this minimum ratio is still not unique, then go on repeating the above outlined procedure till the unique minimum, ratio is obtained to resolve the degeneracy. After the resolution of this tie, Simplex method is applied to obtain the optimum solution.

Que 5.14. Given the linear programming problem :

Maximize $Z = 3x_1 + 5x_2$

Subject to the constraints :

$x_1 \leq 4, x_2 \leq 6, 3x_1 + 2x_2 \leq 18 ; x_1, x_2 \geq 0.$

Discuss the effect on the optimality of the solution, when the objective function is changed to $3x_1 + x_2$.

Answer

1. After introducing the slack variables $S_1 \geq 0, S_2 \geq 0$ and $S_3 \geq 0$ in the constraints of the given LPP by simplex method, the optimum simplex table is :

y_B	C_B	X_B	y_1	y_2	y_3	y_4	y_5
y_3	0	2	0	0	1	2/3	-1/3
y_2	5	6	0	1	0	1	0
y_1	3	2	1	0	0	-2/3	1/3
$Z = \sum C_B a_{ij}$			3	5	0	3	1

2. Since, the objective function is changed to $3x_1 + x_2$, C_2 has been changed to 1 keeping C_1 fixed. So, we find the variation in C_2 .
3. Variation in C_2 : Since $C_2 \in C_B$, the range of ΔC_2 is given by,

$$\text{Minimum}_{y_{2j} > 0} \left\{ \frac{-(Z_j - C_j)}{y_{2j}} \right\} \leq \Delta C_2 \leq \text{Maximum}_{y_{2j} > 0} \left\{ \frac{-(Z_j - C_j)}{y_{2j}} \right\}$$

$$\text{i.e., Minimum } \left\{ \frac{-3}{1} \right\} \leq C_2 < \infty \text{ or } -3 \leq \Delta C_2 \leq \infty$$

$$\therefore 5 - 3 \leq C_2 < 5 + \infty \text{ or } 2 \leq C_2 < \infty.$$

4. This indicates that if C_2 is changed to 1, the optimum solution obtained above does not remain optimal.
5. To find the new optimal solution :

When the objective function $Z = 3x_1 + 5x_2$ is changed to $Z^* = 3x_1 + x_2$;

$$Z_1 - C_1 = Z_2 - C_2 = Z_3 - C_3 = 0;$$

$$Z_4 - C_4 = C_B y_4 - C_4 = -1 \text{ and } Z_5 - C_5 = C_B y_5 - C_5 = 1$$

This shows that y_4 enters the basis and y_3 leaves the basis in the next iteration.

6. Thus, we have the following optimum simplex table :

y_B	C_B	X_B	y_1	y_2	y_3	y_4	y_5
y_3	0	3	0	0	3/2	1	-1/2
y_2	1	3	0	1	-3/2	0	1/2
y_1	3	4	1	0	1	0	0
$Z^* = \sum C_B a_{ij}$			0	0	3/2	0	1/2

\therefore The optimum solution of the revised LPP is,

$$x_1 = 4$$

$$x_2 = 3$$

$$\text{Maximum } Z^* = 15.$$

Que 5.15. Enumerate the special cases that may arise while solving a linear programming problem ?

Answer

- a. Infeasible Solution :**

1. When there is no value of the decision variables that satisfies all the constraints of LPP then it is said to have infeasible solution.

Example : Maximize $Z = 4x_1 + 2x_2$

subject to $2x_1 + 3x_2 \leq 18$

$$x_1 + x_2 \geq 10$$

$$x_1, x_2 \geq 0$$

2. Solution of this expression :

i. Line AB represents

$$2x_1 + 3x_2 = 18$$

and line CD represents

$$x_1 + x_2 = 10$$

ii. In the Fig. 5.15.1 there is no point which satisfies both the constraints in first quadrant. Hence, problem cannot be solved or given LP problem has no feasible solution.

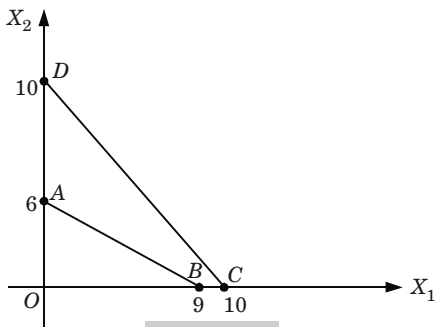


Fig. 5.15.1.

- b. Multiple Optimal Solution :** When more than one value of decision variables yields the same optimal value of objective function, such values of decision variables are known as alternate optimal solutions and LPP is said to have multiple optimal solutions.
- c. Redundancy :** A constraint in the given LPP is said to be redundant if the feasible region of the problem remains unchanged on deleting that constraint.
- d. Unbounded Solution :** When the value of objective function can be increased or decreased infinitely without any limitation, such solution of LPP is known as unbounded solution. In this situation, optimal solution may or may not exist.

Que 5.16. Discuss the transportation problem.

Answer

1. The transportation problem deals with the transportation of a product manufactured at different plants or factories to a number of different warehouses.
2. The objective is to satisfy the destination requirements within the plant's capacity constraints at the minimum transportation cost.

- Thus transportation problem typically arise in situations involving physical movement of goods from plants to warehouses, warehouses to wholesalers, wholesalers to retailers and retailers to customers.
- Solution of the transportation problem requires the determination of how many units should be transported from each supply origin to each demand destination in order to satisfy all the destination demands while minimizing the total associated cost of transportation.

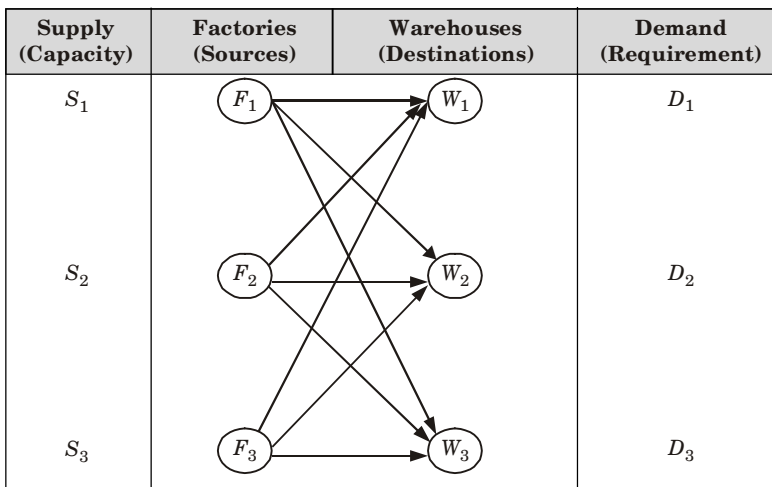


Fig. 5.16.1. Transportation problem chart.

Que 5.17. Write mathematical model for general transportation problem.

Answer

- The general transportation problem can be stated mathematically as follows :

Let a_i = Quantity of product available at origin i ,

b_j = Quantity of product required at destination j ,

C_{ij} = The cost of transporting one unit of product from origin i to destination j , and

x_{ij} = The quantity transported from origin i to destination j .

- Assume that $\sum_{i=1}^m a_i = \sum_{j=1}^n b_j$ by which means that the total quantity available at the origin is precisely equal to the total amount required at the destinations.
- With these, the problem can be stated as a linear programming problem as :

$$\text{Minimize total cost } Z = \sum_{i=1}^m \sum_{j=1}^n C_{ij} x_{ij}$$

$$\text{Subject to } \sum_{j=1}^n x_{ij} = a_i \quad \text{for } i = 1, 2, \dots, m$$

$$\sum_{i=1}^m x_{ij} = b_j \quad \text{for } j = 1, 2, \dots, n$$

$$\text{and } x_{ij} \geq 0 \quad \text{for all } i = 1, 2, \dots, m, \text{ and } j = 1, 2, \dots, n.$$

Que 5.18. Write short notes on :

- North-west corner method,
- Least-cost method, and
- Vogel's approximation method (or Penalty method).

Answer

- a. North-West Corner Method :** It is a simple and efficient method to obtain an initial basic feasible solution. Various steps of the method are :

Step 1 :

Select the north-west (upper left hand) corner cell of the transportation table and allocate as much as possible so that either the capacity of the first row is exhausted or the destination requirement of the first column is satisfied, i.e., $x_{11} = \min(a_1, b_1)$, where b_1 is the capacity of the first row and a_1 is the requirement of first column.

Step 2 :

- If $b_1 > a_1$, we move down vertically to the second row and make the second allocation of magnitude $x_{21} = \min(a_2, b_1 - x_{11})$ in the cell (2, 1).
- If $b_1 < a_1$, we move right horizontally to the second column and make the second allocation of magnitude $x_{12} = \min(a_1 - x_{11}, b_2)$ in the cell (1, 2).
- If $b_1 = a_1$, there is a tie for the second allocation. One can make the second allocation of magnitude

$$x_{12} = \min(a_1 - a_1, b_1) = 0 \text{ in the cell (1, 2).}$$

$$x_{21} = \min(a_2, b_1 - b_1) = 0 \text{ in the cell (2, 1).}$$

Step 3 :

Repeat step 1 and 2 moving down towards the lower/right corner of the transportation table until all the requirements are satisfied.

- b. Least-Cost Method :** This method takes into account the minimum unit cost and can be summarized as follows :

Step 1 :

- Determine the smallest cost in the cost matrix of the transportation table. Let it be C_{ij} allocate $x_{ij} = \min(a_i, b_j)$ in the cell (i, j).

Step 2 :

1. If $x_{ij} = a_i$ cross-off the i^{th} row of the transportation table and decrease b_j by a_i . Go to step 3.
2. If $x_{ij} = b_j$ cross-off the j^{th} column of the transportation table and decrease a_i by b_j . Go to step 3.
3. If $x_{ij} = a_i = b_j$ cross-off the i^{th} row or j^{th} column but not both.

Step 3 :

1. Repeat steps 1 and 2 for the resulting reduced transportation table until all the requirements are satisfied. Whenever the minimum cost is not unique, make an arbitrary choice among the minima.
- c. Vogel's Approximation Method (Or Penalty Method) :** The Vogel's approximation method takes into account not only the least cost C_{ij} but also the costs that just exceed C_{ij} . The steps of the method are given below :

Step 1 :

1. For each row of the transportation table identify the smallest and the next to smallest costs. Determine the difference between them for each row.
2. Display them alongside the transportation table by enclosing them in parenthesis against the respective rows. Similarly, compute the differences for each column.

Step 2 :

1. Identify the row or column with the largest difference among all the rows and columns. If a tie occurs, use any arbitrary tie-breaking choice.
2. Let the greatest difference correspond to i^{th} row and let C_{ij} be the smallest cost in the i^{th} row.
3. Allocate the maximum feasible among $x_{ij} = \min(a_i, b_j)$ in the $(i, j)^{\text{th}}$ cell and cross-off either the i^{th} row or the j^{th} column in the usual manner.

Step 3 :

Recompute the column and row differences for the reduced transportation table and go to step 2. Repeat the procedure until all the rim requirements are satisfied.

Que 5.19. Determine an initial basic feasible solution to the

following transportation problem using :

- a. North-west corner rule, and
- b. Least-cost method.

		To			Supply
		A	B	C	
From	a	2	7	4	5
	b	3	3	1	8
	c	5	4	7	7
	d	1	6	2	14
Demand		7	9	18	

Answer**a. North-West Corner Rule :**

1. Select the north-west (upper left hand) corner cell of the transportation table and allocating as much as possible,

	A	B	C	
a	2(5)	7	4	5/0
b	3	3	1	8
c	5	4	7	7
d	1	6	2	14
	7/2	9	18	

2. For second allocation selecting the north-west corner cell of the remaining transportation table and allocating as much as possible,

	A	B	C	
a	2(5)	7	4	0
b	3(2)	3	1	8/6
c	5	4	7	7
d	1	6	2	14
	2/0	9	18	

3. Similarly, selecting the north-west corner cell and allocating maximum possible,

	A	B	C	
a	2(5)	7	4	0
b	3(2)	3(6)	1	6/0
c	5	4	7	7
d	1	6	2	14
	0	9/3	18	

4. Similarly, selecting the north-west corner cell and allocating maximum possible,

	A	B	C	
a	2(5)	7	4	0
b	3(2)	3(6)	1	0
c	5	4(3)	7	7/4
d	1	6	2	14
	0	3/0	18	

5. Selecting and allocating the remaining part so that the capacity and destination requirement is fulfilled.

	A	B	C	
a	2(5)	7	4	0
b	3(2)	3(6)	1	0
c	5	4(3)	7(4)	4/0
d	1	6	2(14)	14/0
	0	0	18/0	

6. Hence, final allocation is shown below :

	A	B	C	
a	2(5)	7	4	5
b	3(2)	3(6)	1	8
c	5	4(3)	7(4)	7
d	1	6	2(14)	14
	7	9	18	

7. Total transportation cost

$$= (2 \times 5) + (3 \times 2) + (3 \times 6) + (4 \times 3) + (7 \times 4) + (2 \times 14)$$

$$= 10 + 6 + 18 + 12 + 28 + 28 = 102 \text{ units.}$$

b. Least Cost Method :

1. Selecting the smallest cost in the cost matrix of the transportation table and allocating maximum possible allocation :

	A	B	C	
a	2	7	4	5
b	3	3	1(8)	8/0
c	5	4	7	7
d	1(7)	6	2	7
	0	9	18/10	

2. For second allocation selecting smallest cost in the remaining cost transportation cost and allocating them,

	A	B	C	
a	2	7	4	5
b	3	3	1(8)	8
c	5	4	7	7
d	1(7)	6	2	14/7
	7/0	9	18	

3. Similarly, selecting cost in the cost table and allocating them,

	A	B	C	
a	2	7	4	5
b	3	3	1(8)	0
c	5	4	7	7
d	1(7)	6	2(7)	7/0
	0	9	10/3	

4. Similarly, selecting smallest cost in the cost table and allocating them,

	A	B	C	
a	2	7	4(3)	5/2
b	3	3	1(8)	0
c	5	4(7)	7	7/0
d	1(7)	6	2(7)	0
	0	9/2	3/0	

5. Selecting and allocating the remaining part so that the capacity and requirement is fulfilled.

	A	B	C	
a	2	7(2)	4(3)	2/0
b	3	3	1(8)	0
c	5	4(7)	7	0
d	1(7)	6	2(7)	0
	0	2/0	3/0	

6. Final allocation is given by,

	A	B	C	
a	2	7(2)	4(3)	5
b	3	3	1(8)	8
c	5	4(7)	7	7
d	1(7)	6	2(7)	14
	7	9	18	

7. Total transportation cost,

$$= (7 \times 2) + (4 \times 3) + (1 \times 8) + (4 \times 7) + (1 \times 7) + (2 \times 7)$$

$$= 14 + 12 + 8 + 28 + 7 + 14 = 83 \text{ units.}$$

Que 5.20. Use Vogel's approximation method (VAM) to find initial basic feasible solution to the transportation problem.

	D_1	D_2	D_3	D_4	Supply
S_1	19	30	50	10	7
S_2	70	30	40	60	9
S_3	40	8	70	20	18
Demand	5	8	7	14	34

Answer

1. Checking the balancing of transportation problem,

	D_1	D_2	D_3	D_4	Supply
S_1	19	30	50	10	7
S_2	70	30	40	60	9
S_3	40	8	70	20	18
Demand	5	8	7	14	34

= 34

= 34

2. Since, total demand = total supply
 Therefore, this is a balanced transportation problem.
3. Assign penalties for each row and column. Then allocate highest penalty with maximum possible allocation.

	D_1	D_2	D_3	D_4	Supply	Penalty
S_1	19	30	50	10	7	$19 - 10 = 9$
S_2	70	30	40	60	9	$40 - 30 = 10$
S_3	40	8(8)	70	20	18/10	$20 - 8 = 12$
Demand	5	8/0	7	14		
Penalty	$40 - 19 = 21$	$30 - 8 = 22$	$50 - 40 = 10$	$20 - 10 = 10$		

↑

4. Calculating the penalty for remaining transportation problem.
5. Assign penalties for each row and column. Then allocate highest penalty with maximum possible allocation.

	D_1	D_3	D_4	Supply	Penalty
S_1	19(5)	50	10	7/2	$19 - 10 = 9$
S_2	70	40	60	9	$60 - 40 = 20$
S_3	40	70	20	10	$40 - 20 = 20$
Demand	5/0	7	14		
Penalty	21	10	10		

↑

6. Similarly, calculating and assigning penalties for remaining transportation problem and allocating highest penalty with maximum possible allocation.

	D_3	D_4	Supply	Penalty
S_1	50	10	2	40
S_2	40	60	9	20
S_3	70	20(10)	10/0	50 ←
Demand	7	14/4		
Penalty	10	10		

7. Similarly, repeating the above step for remaining transportation problem and allocating highest penalty with maximum possible allocation,

	D_3	D_4	Supply	Penalty
S_1	50	10(2)	2/0	40
S_2	40(7)	60(2)	9	20
Demand	7	4/2		
Penalty	10	50		

↑

8. Final allocation of transportation is given,

	D_1	D_2	D_3	D_4	Supply
S_1	19(5)	30	50	10(2)	7
S_2	70	30	40(7)	60(2)	9
S_3	40	8(8)	70	20(10)	18
Demand	5	8	7	14	

9. Total cost = $(19 \times 5) + (10 \times 2) + (40 \times 7) + (60 \times 2) + (8 \times 8) + (20 \times 10)$
 $= 95 + 20 + 280 + 120 + 64 + 200 = 779$

Que 5.21. What is degeneracy ? How does problem of degeneracy arise in transportation problem ? How can we deal with this problem ? Solve the following transportation problem for maximum profit.

Warehouse		Market			
		A	B	C	D
	X	12	18	6	25
	Y	8	7	10	18
	Z	14	3	11	20

Available units at warehouses : X : 200, Y : 500, Z : 300.

Demand in market : A : 180, B : 320, C : 100, D : 400 units.

Answer

A. Degeneracy in Transportation Problem :

1. A basic feasible solution for the general transportation problem must consist of $(m + n - 1)$ occupied cells.

2. The basic solution will be called degenerate when the number of occupied cells is less than the required number ($m + n - 1$).
3. Degeneracy can occur in initial solution or it may arise in some subsequent iterations.

B. Problem Arises and Solution in Degeneracy :

1. We have seen that in case of simplex algorithm, the basic feasible solution may become degenerate at the initial stage or at some intermediate stage of computation.
2. In a transportation problem with m origins and n destinations if a basic feasible solution has less than $m + n - 1$ allocation (occupied cells), the problem is said to be a degenerate transportation problem.
3. Degeneracy can occur in the initial solution or during some subsequent iteration.

a. Degeneracy in the Initial Solution :

1. Normally, while finding the initial solution, any allocation made either satisfies supply or demand, but not both.
2. If, however both supply and demand are satisfied simultaneously, row as well as column are cancelled simultaneously and the number of allocations become one less than $m + n - 1$.
3. If this phenomenon occurs twice, the number of allocations becomes two less than $m + n - 1$ and so on.
4. This degeneracy is resolved or the above degenerate solution is made non-degenerate in the following manner :
 - i. First of all the requisite numbers of vacant cells with least unit costs are chosen so that :
 1. These cells plus the existing number of allocations are equal to $m + n - 1$.
 2. These $m + n - 1$ cells are in independent positions *i.e.*, no closed path (loop) can be formed among them. If a loop is formed cell / cells with next lower cost is /are chosen so that no loop is formed among them. This can always be done if the solution we start with contains allocated cells in independent positions.
 - ii. Now allocate an infinitesimally small but positive value ϵ (Greek letter epsilon) to each of the chosen cells. Subscripts are used when more than one such letter is required (e.g., ϵ_1, ϵ_2 , etc.).
 - iii. These ϵ 's are then treated like any other positive basic variable and are kept in the transportation array (matrix) until temporary degeneracy is removed or until the optimal solution is reached, whichever occurs first. At that point we set each $\epsilon = 0$. Notice that ϵ is infinitesimally small and hence its effect can be neglected when it is added to or subtracted from a positive value (e.g., $10 + \epsilon = 10, 5 - \epsilon = 5, \epsilon + \epsilon = 2\epsilon, \epsilon - \epsilon = 0$).

iv. Consequently, they do not appreciably alter the physical nature of the original set of allocations but do help in carrying out further computations such as optimality test.

b. Degeneracy During Some Subsequent Iteration :

1. Sometimes even if the starting feasible solution is non-degenerate, degeneracy may develop later at some subsequent iteration.
2. This happens when the selection of the entering variable (least value in the closed path that has been assigned a negative sign), causes two or more current basic variables (allocated cell values) to become zero.
3. In this case we allocate ϵ to recently vacated cell with least cost so that there are exactly $m + n - 1$ allocated cells in independent positions and the procedure can then be continued in the usual manner and apply the common difference method for this allocation.

C. Numerical :

1. Convert transportation problem into minimization type problem,

	A	B	C	D	S	Penalty			
X	13	7(200)	19	0	200/0	7	—	—	—
Y	17	18(100)	15	7(400)	500/100/0	8	[8]	2	3
Z	11(180)	22(20)	14(100)	5	300/120/20/0	6	6	3	[6]
D	180/0	320/120/0	100/0	400/0					
	2	[11]	1	5					
	6	4	1	2					
Penalty	[6]	4	1	—					
	—	4	1	—					

2. All allocation in minimization table,

	A	B	C	D	Supply
X	13	7(200)	19	0	200
Y	17	18(100)	15	7(400)	500
Z	11(180)	22(20)	14(100)	5	300

Demand 180 320 100 400

3. Actual transportation table : This is optimal feasible solution because $m + n - 1 = 6$ in maximum profit table.

	A	B	C	D	Supply
X	12	18(200)	6	25	200
Y	8	7(100)	10	18(400)	500
Z	14(180)	3(20)	11(100)	20	300
	Demand 180	320	100	400	

4. Maximum profit of this transportation is
 $= (200 \times 18) + (100 \times 7) + (400 \times 18) + (180 \times 14) + (20 \times 3) + (100 \times 11)$
 $= \text{Rs. } 15180.$

Que 5.22. What do you mean by assignment problem ? How will you formulate it mathematically ?

Answer

A. Assignment Problem : The assignment problem is a special case of the transportation problem in which the objective is to assign a number of resources to equal number of activities at a minimum cost.

B. Mathematical Formulation of Assignment Problem :

1. Consider a problem of assignment of n resources (workers) to n activities (jobs) so as to minimize the overall cost or time in such a way that each resource can associate with one and only one job.
2. The cost (or effectiveness) matrix (c_{ij}) is given as under :

	Activity				Available
	A_1	A_2	\cdots	A_n	
R_1	c_{11}	c_{12}	\cdots	c_{1n}	1
R_2	c_{21}	c_{22}	\cdots	c_{2n}	1
Resource \vdots	\vdots	\vdots	\vdots	\vdots	\vdots
R_n	c_{n1}	c_{n2}	\cdots	c_{nn}	1
Required	1	1	\cdots	1	

3. The cost matrix is same as that of a transportation problem except that availability at each of the resources and the requirement at each of the destinations is unity (due to the fact that assignments are made on a one-to-one basis).
4. Let x_{ij} denote the assignment of i^{th} resource to j^{th} activity, such that

$$x_{ij} = \begin{cases} 1, & \text{if resource } i \text{ is assigned to activity } j \\ 0, & \text{otherwise} \end{cases}$$

5. Then, the mathematical formulation of the assignment problem is

Minimize $z = \sum_{i=1}^n \sum_{j=1}^n c_{ij} x_{ij}$ subject to the constraints :

$$\sum_{i=1}^n x_{ij} = 1 \text{ and } \sum_{j=1}^n x_{ij} = 1 ; x_{ij} = 0 \text{ or } 1$$

for all $i = 1, 2, \dots, n$ and $j = 1, 2, \dots, n$.

c_{ij} is the cost associated with assigning to i^{th} activity.

Que 5.23. Explain the variations of the assignment problem.

Answer

Variations of the assignment problem are as follows :

a. The Maximal Assignment Problem :

1. Sometimes, the assignment problem deals with the maximization of an objective function rather than to minimize it. For example, it may be required to assign persons to jobs in such a way that the expected profit is maximum.
2. Such problem may be solved easily by first converting it to a minimization problem and then applying the usual procedure of assignment algorithm.
3. This conversion can be very easily done by subtracting from the highest element, all the elements of the given profit matrix, or equivalently, by placing minus sign before each element of the profit matrix in order to make it cost matrix.

b. Restrictions on Assignment :

1. Sometimes technical, legal or other restrictions do not permit the assignment of a particular facility to a particular job.
2. Such difficulty can be overcome by assigning a very high cost to the corresponding cell, so that the activity will be automatically excluded from the optimal solution.

Que 5.24. Explain Hungarians method for assignment problems.

Answer

1. The Hungarian assignment method provides us with an efficient means of finding of the optimal solution without having to make a direct comparison of every option.
2. It operates on principle of matrix reduction. This just means that by subtracting and adding appropriate numbers in the cost table or matrix, we can reduce the problem to matrix of opportunity costs.
3. If we can reduce the matrix to the point where there is one zero element in each row and column, it will then be possible to make optimal assignments *i.e.*, in which all the opportunity costs are zero.

4. Hungarian method of assignment problem can be summarized in the following steps :

Step 1 : Find the opportunity cost table by :

- a. Subtracting the smallest number in each row of the original cost table matrix from every number in that row.
- b. Then subtracting the smallest number in each column of the table obtained from every number in that column.

Step 2 : Make assignments in the opportunity cost matrix in the following ways :

- a. Examine the rows successively until a row with exactly one unmarked zero found. Enclose this zero in a box (\square) as an assignment will be made there and (\times) all other zeros appearing in the corresponding column as they will not be considered for future assignment. Proceed in this way until all the rows have been examined.
- b. After examining all the rows completely, examine the columns successively until a column with exactly one unmarked zero is found. Make an assignment to the single zero by putting square (\square) around it and cross out (\times) all other zeros appearing in the corresponding row as they will not be used to make any other assignment in that row. Proceed in this manner until all columns have been examined.
- c. Repeat the operations (a) and (b) successively until one of the following situation arises :
 - i. All the zeros in rows or columns are either marked (\square) or crossed (\times) and there is exactly one assignment in each row and in each column. In such a case optimal assignment policy for the given problem is obtained.
 - ii. There may be some rows (or columns) without assignment, *i.e.*, the total number of marked zeros is less than the order of the matrix.

Step 3 : Develop the new revised opportunity cost table :

- a. An optimal solution is seldom obtained from the initial opportunity cost table.
- b. Often we will need to revised the table in order to shift one (or more) of the zero costs from its present location to a new uncovered location to emerge with a new zero opportunity cost.
- c. This is accomplished by subtracting the smallest number not covered by a line from a number not covered by the straight line.
- d. This same smallest number is then added to every number (including zeros) lying at the intersection of any two lines.

Step 4 : Repeat step 2 to step 3 until an optimal solution is obtained.

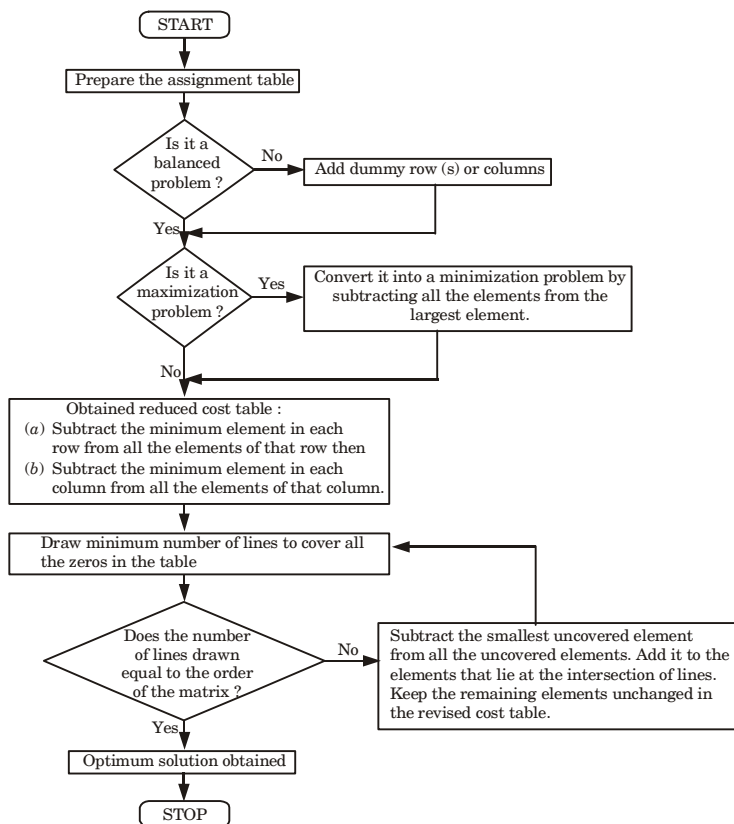


Table. 5.24.1. Flow chart for the Hungarian method.

Que 5.25. A machine tool company decides to make four subassemblies through four contractors. Each contractor is to receive only one subassembly. The cost of each subassembly is determined by the bids submitted by each contractor and is shown in table in hundreds of rupees.

		Contractors			
		1	2	3	4
Subassemblies	1	15	13	14	17
	2	11	12	15	13
	3	13	12	10	11
	4	15	17	14	16

- A. Formulate the mathematical model for the assignment problem.**
B. Assign the different subassemblies to contractors so as to minimize the total cost.

Answer

A. Formulation of the Model :

Step 1 : Key decision is what to whom *i.e.*, which subassembly be assigned to which contractor or what are the 'n' optimum assignments on 1-1 basis.

Step 2 : Feasible alternatives are $n!$ possible arrangements for $n \times n$ assignment situation. In the given situation there are $4!$ different arrangements.

Step 3 : Objective is to minimize the total cost involved.

$$\text{i.e., Minimize } Z = \sum_{i=1}^n \sum_{j=1}^n c_{ij}x_{ij}.$$

Step 4 : Constraints :

1. Constraints on subassemblies are :

$$x_{11} + x_{12} + x_{13} + x_{14} = 1$$

$$x_{21} + x_{22} + x_{23} + x_{24} = 1$$

$$x_{31} + x_{32} + x_{33} + x_{34} = 1$$

$$x_{41} + x_{42} + x_{43} + x_{44} = 1$$

2. Constraints on contractors are :

$$x_{11} + x_{21} + x_{31} + x_{41} = 1$$

$$x_{12} + x_{22} + x_{32} + x_{42} = 1$$

$$x_{13} + x_{23} + x_{33} + x_{43} = 1$$

$$x_{14} + x_{24} + x_{34} + x_{44} = 1$$

B. Assignment :

Step 1 : Subtracting the smallest element of each row from every element of the corresponding row, we get the reduced matrix.

2	0	1	4
0	1	4	2
3	2	0	1
1	3	0	2

Step 2 : Subtracting the smallest element of each column of the reduced matrix from every element of the corresponding column, we get the following reduced matrix :

2	0	1	3
0	1	4	1
3	2	0	0
1	3	0	1

Step 3 : Starting with row 1, we enrectangle (\square) (*i.e.*, make assignment) a single zero, if any, and cross (\times) all other zeros in the column so marked. Thus, we get

2	$\square 0$	1	3
$\square 0$	1	4	1
3	2	\times	$\square 0$
1	3	$\square 0$	1

The optimal assignment is :

$1 \rightarrow 2, 2 \rightarrow 1, 3 \rightarrow 4$, and $4 \rightarrow 3$.

Therefore minimum total cost = $(13 + 11 + 11 + 14) \times 100 = \text{Rs. } 4900$.

Que 5.26. Five wagons are available at stations 1, 2, 3, 4, and 5.

These are required at five stations *I, II, III, IV*, and *V*. The mileages between various stations are given by the table below. How should the wagons be assigned so as to minimize the total mileage covered ?

	I	II	III	IV	V
1	10	5	9	18	11
2	13	9	6	12	14
3	3	2	4	4	5
4	18	9	12	17	15
5	11	6	14	19	10

Answer

Step 1 : Subtracting the smallest element of each row from every element of the corresponding row, we get the reduced matrix.

	I	II	III	IV	V
1	5	0	4	13	6
2	7	3	0	6	8
3	1	0	2	2	3
4	9	0	3	8	6
5	5	0	8	13	4

Step 2 : Subtracting the smallest element of each column of the reduced matrix from every element of the corresponding column, we get the following reduced matrix :

	I	II	III	IV	V
1	4	0	4	11	3
2	6	3	0	4	5
3	0	0	2	0	0
4	8	0	3	6	3
5	4	0	8	11	1

Step 3 : Starting with row 1, we enrectangle (\square) (*i.e.*, make, assignment) a single zero, if any, and cross (\times) other zeros in the column so marked. Thus, we get

4	$\square 0$	4	11	3
6	3	$\square 0$	4	5
$\square 0$	\times	2	\times	\times
8	\times	3	6	3
4	\times	8	11	1

Step 4 :

1. Since rows 4 and 5 do not have any assignment, we mark these rows (\checkmark).
2. Now there is a zero in the column of the marked rows. So, we mark second column (\checkmark).
3. Further there is an assignment in the first row of the ticked column. So, we marked first row (\checkmark).
4. Draw straight lines through all unmarked rows and marked columns. Thus we have.

	I	II	III	IV	V	
1	4	$\square 0$	4	11	3	\checkmark
2	6	3	$\square 0$	4	5	---
3	$\square 0$	\times	2	\times	\times	---
4	8	\times	3	6	3	\checkmark
5	4	\times	8	11	1	\checkmark

5. In last step, we observe that the minimum number of lines so drawn is 3, which is less than the order of the cost matrix, indicating that the current assignment is not optimum.
6. To increase the minimum number of lines, we generate new zeros in the modified matrix.
7. The smallest element not covered by the lines is 1.

8. Subtracting this element from all the uncovered elements and adding the same to all the elements at the intersection of the lines, we obtain the following new reduced matrix.

	I	II	III	IV	V
1	3	0	3	10	2
2	6	4	0	4	5
3	0	1	2	0	0
4	7	0	2	5	2
5	3	0	7	10	0

Step 5 : Repeating the step 3 and 4, for the optimal solution.

	I	II	III	IV	V	
1	3	0	3	10	2	✓
2	6	4	0	4	5	✓
3	0	1	2	0	0	✓
4	7	0	2	5	2	✓
5	3	0	7	10	0	✓

	I	II	III	IV	V
1	1	0	1	8	0
2	6	6	0	4	5
3	0	3	2	0	0
4	5	0	0	3	0
5	3	2	7	10	0

Step 6 : This is not optimal further check the optimal solution repeating the step 3 and 6.

	I	II	III	IV	V	
1	1	0	1	8	0	✓
2	6	6	0	4	5	✓
3	0	3	2	0	0	✓
4	5	0	0	3	0	✓
5	3	2	7	10	0	✓

	I	II	III	IV	V
1	0	0	1	7	0
2	5	6	0	3	5
3	0	4	3	0	1
4	4	0	0	2	0
5	2	2	7	9	0

Assignment the above matrix, we get,

	I	II	III	IV	V
1	0	8	1	7	8
2	5	6	0	3	5
3	8	4	3	0	1
4	4	0	8	2	8
5	2	2	7	9	0

Now, since each row and each column has one and only one assignment, an optimal solution is reached. Thus, the optimum assignment is :

1 → I, 2 → III, 3 → IV, 4 → II, and 5 → V

The minimum total mileage associated with this solution is

$$Z_{\min} = 10 + 6 + 4 + 9 + 10 = 39$$

PART-3

Optimality Test : The Stepping Stone Method, and MODI Method, Simulation.

CONCEPT OUTLINE

Types of Simulation :

1. Analogue simulation.
2. Computer simulation.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 5.27. Explain stepping stone method.

Answer

This method is an alternative procedure for the solution of a transportation problem. Various steps involved in this method are summarized below :

Step 1 : Find the initial basic feasible solution of the transportation problem.

Step 2 : Check the number of occupied cells. If there are less than $m + n - 1$, there exists degeneracy and we introduce a very small quantity

$\in (\rightarrow 0)$ in suitable independent positions, so that the number of occupied cells is exactly equal to $m + n - 1$.

Step 3 : Compute improvement index for each of the unoccupied cells. This is computed by calculating the opportunity cost of an unoccupied cell. This means that if we shift one unit from a cell containing positive shipment to the unoccupied cell, it will be the net cost. If all the unoccupied cells have positive improvement index, then the given solution is an optimum solution.

Step 4 : If there are several unoccupied cells with negative improvement indices, then we select the cell having the largest negative improvement index and shift the maximum possible units to that cell without violating the supply and demand constraints. After it, again go to step 3.

Que 5.28. What is MODI method ? Write down the steps involved in solution of transportation problem using MODI method.

Answer

A. MODI Method : The modified distribution method or MODI method is an efficient method of checking the optimality of the initial feasible solution.

B. Steps for Solving Transportation Problem using MODI Method :

Step 1 : Find the initial basic feasible solution.

Step 2 : Check the number of occupied cells. If there are less than $m + n - 1$, there exists degeneracy and we introduce a very small positive assignment of $\in (\approx 0)$ in suitable independent positions, so that the number of occupied cells is exactly equal to $m + n - 1$.

Step 3 : For each occupied cell in the current solution, solve the system of equations $u_i + v_j = c_{ij}$ starting initially with some $u_i = 0$ or $v_j = 0$ and entering successively the values of u_i and v_j in the transportation table margins.

Step 4 : Compute the net evaluations $z_{ij} - c_{ij} = u_i + v_j - c_{ij}$ for all unoccupied basic cells and enter them in the lower left corners of the basics.

Step 5 :

1. Let the unoccupied cell (r, s) enter the basics. Allocate an unknown quantity, say θ , to the cell (r, s) . Identify a loop that start and ends at the cell (r, s) and connects some of the basic cells.
2. Add and subtract interchangeably, θ to and from the transition cells of the loop in such a way that the requirements remain satisfied.

Step 6 :

1. Assign a maximum value to θ in such a way that the value of one basic variable becomes zero and the other basic variable remains non-negative.

2. The basic cell where allocation has been reduced to zero leaves the basis.

Step 7 : Return to step 3 and repeat the process until an optimum basic feasible solution has been obtained.

Que 5.29. Find the optimum solution to the following transportation problem in which the cells contain the transportation cost in rupees.

	1	2	3	4	5	Supply
Warehouses						
1	7	6	4	5	9	40
2	8	5	6	7	8	30
3	6	8	9	6	5	20
4	5	7	7	8	6	10
Demand	30	30	15	20	5	

Answer

1. Checking the balance of transportation problem,

	1	2	3	4	5	Supply
1	7	6	4	5	9	40
2	8	5	6	7	8	30
3	6	8	9	6	5	20
4	5	7	7	8	6	10
Demand	30	30	15	20	5	100 (Total)

2. We shall use Vogel's approximation method to find initial feasible solution.

	1	2	3	4	5	Supply	Penalty
1	7(5)	6	4(15)	5(20)	9	40/25/5/0	1 1 [2] 2
2	8	5(30)	6	7	8	30/0	1 [2] — —
3	6(15)	8	9	6	5(5)	20/15/10	1 1 1 [1]
4	5(10)	7	7	8	6	10/0	1 1 1 1
Demand	30/25/ 15/0	30/0	15/0	20/0	5/0		
	1	1	[2]	1	1		
	1	1	—	1	1		
Penalties	1	—	—	1	1		
	1	—	—	—	1		

3. To test the basic feasible solution for optimality total number of allocations should be $(m + n - 1)$ i.e., $(5 + 4 - 1) = 8$.
4. But the total allocations are 7, so there is degeneracy in the problem.

5. Thus we allocate the unknown quantity ϵ to the cell (1, 2) or (2, 3).
6. Let us allocate it to cell (2, 3), so that the number of allocated cells becomes 8.

	1	2	3	4	5
1	7(5)	6	4(15)	5(20)	9
2	8	5(30)	6(ϵ)	7	8
3	6(15)	8	9	6	5(5)
4	5(10)	7	7	8	6

7. The optimality test can be performed by the following step :
- i. Matrix of (u_i, v_j) for allocated cells.

		v_j				
		0	-4	-3	-2	-1
u_i	7	7		4	5	
	9		5	6		
	6	6				5
	5	5				

- ii. Matrix with cell value of $(u_i + v_j)$ for empty cells.

		v_j				
		0	-4	-3	-2	-1
u_i	7	.	3	.	.	6
	9	9	.	.	7	8
	6	.	2	3	4	.
	5	.	1	2	3	4

- iii. Let

$$v_1 = 0$$

- iv. Now calculating u_i and v_i for all occupied cell,

$$\begin{array}{llll}
 u_1 + v_1 = C_{11} & \Rightarrow & u_1 + 0 = 7 & \Rightarrow u_1 = 7 \\
 u_3 + v_1 = C_{31} & \Rightarrow & u_3 + 0 = 6 & \Rightarrow u_3 = 6 \\
 u_4 + v_1 = C_{41} & \Rightarrow & u_4 + 0 = 5 & \Rightarrow u_4 = 5 \\
 u_1 + v_3 = C_{13} & \Rightarrow & 7 + v_3 = 4 & \Rightarrow v_3 = -3 \\
 u_1 + v_4 = C_{14} & \Rightarrow & 7 + v_4 = 5 & \Rightarrow v_4 = -2 \\
 u_3 + v_5 = C_{35} & \Rightarrow & 6 + v_5 = 5 & \Rightarrow v_5 = -1 \\
 u_2 + v_3 = C_{23} & \Rightarrow & u_2 - 3 = 6 & \Rightarrow u_2 = 9 \\
 u_2 + v_2 = C_{22} & \Rightarrow & 9 + v_2 = 5 & \Rightarrow v_2 = -4
 \end{array}$$

- v. Now to calculate the unoccupied cell and put it on the cell evaluation,

$$z_{12} = u_1 + v_2 - C_{12} = 3$$

$$z_{15} = u_1 + v_5 - C_{15} = 3$$

$$z_{21} = u_2 + v_1 - C_{21} = 7$$

$$z_{24} = u_2 + v_4 - C_{24} = 0$$

$$z_{25} = u_2 + v_5 - C_{25} = 0$$

$$z_{32} = u_3 + v_2 - C_{32} = 0$$

$$z_{33} = u_3 + v_3 - C_{33} = 0$$

-	5		15	+	20	
+		30	€			
	15					5
	10					

Initial feasible solution with closed path.

5-€		15+€	20	
€	30			
15				5
10				



5		15	20	
€	30			
15				5
10				

2nd feasible solution

8. For checking optimality :

i. Repeating step I, we get

v_j	0	-3	-3	-2	-1
u_i					
7	7		4	5	
8	8				
6	6				5
5	5				

Matrix of (u_i, v_j) for allocated cells.

Cell evaluation matrix $(u_i + v_j - C_{15})$

·	2	·	·	6
·	·	1	1	1
·	5	6	2	·
·	5	5	5	2

v_j	0	-3	-3	-2	-1
u_i					
7	·	3	·	·	6
8	·	·	5	6	7
6	·	3	3	4	·
5	·	2	2	3	4

Matrix with cell value of $(u_i + v_j)$ for empty cells.

- ii. All cell values are positive; the second feasible solution is optimal.
 iii. Therefore optimal transportation is,

	1	2	3	4	5	Supply
1	7(5)	6	4(15)	5(20)	9	40
2	8(€)	5(30)	6	7	8	30
3	6(15)	8	9	6	5(5)	20
4	5(10)	7	7	8	6	10
Demand	30	30	15	20	5	

- iv. Therefore, total transportation cost is,

$$= \text{Rs. } (7 \times 5) + (4 \times 15) + (20 \times 5) + (8 \times \infty) + (5 \times 30) + (6 \times 15) + (5 \times 5) + (10 \times 5)$$

$$= \text{Rs. } [35 + 60 + 100 + 0 + 150 + 90 + 25 + 50] = \text{Rs. } 510.$$

Que 5.30. What is simulation ? Explain elements and structure of simulation system ?

Answer

A. Simulation :

1. There are many problems of real life, which cannot be represented mathematically due to the complexity and probabilistic nature or problems.
2. It determines the effect of alternative policies without disturbing the system.
3. Simulation is technique for carrying out experiments for analyzing the behaviour and evaluating the performance of real system in actual environment, on simplified system.
4. Simulation is a representation of reality through a use of a model or other device, which will react in the same manner as reality under a given set of conditions.
5. Simulation is defined as the use of a system model that has the designed characteristics of reality in order to produce the essence of actual operation.

B. Elements and Structure of Simulation System :

- a. State Variables :** Depending upon the nature of the problem, a number of variables are required to describe the physical system. These variables are known as state variables.
- b. Random Variables :** The random variable is a real valued function defined over a sample space associated with the outcome of a conceptual chance experiment.
- c. Event :** An event is an occurrence, which causes change in the state variables as a result of which there is a change in the state of the system.
- d. Static and Dynamic Simulation Model :** A static simulation model studies the profile of a system at a particular point of time.
- e. Random Number :** It is a number in a sequence of numbers whose probability of occurrence is same as that of any other number in that sequence.

Que 5.31. Write down various steps of simulation process.

Answer

Various steps of simulation process are as follows :

Step 1 : Identify and clearly define the problem.

Step 2 : List the statement of objectives decision variables and decision rules of the problem.

Step 3 : Formulate an appropriate model of the given problem.

Step 4 : Test the model, compare its behaviour with the behaviour of the actual problem environment.

Step 5 : Identify and collect the data needed to test the model.

Step 6 : Run the simulation model.

Step 7 : Analyze the results of the simulation. If the simulation process complete, then select the best course of action otherwise make the desired changes in model decision variables, parameters and return to step 4.

Step 8 : Re-run the simulation to test the new solution.

Step 9 : Validate the simulation, *i.e.*, increase the chances that any inferences draw about the real situation from running the simulation will be valid.

Que 5.32. What are the advantages, limitations and applications of simulation ?

Answer

A. Advantages of simulation :

1. It is an efficient tool to solve the problems where it is expensive, difficult to conduct experiments on real system.
2. There is no sufficient time to allow the real system to operate extensively.
3. Simulation is useful in sharpening the managerial decision making skills through gaming without disturbing normal operations.
4. Simulation models can be used to conduct experiments without disrupting real system. Experimenting with real system can be very expensive.
5. It enables the manager to provide insight into certain managerial problems where analytical solution of a problem is not possible.
6. Non-technical manager can comprehend simulation more easily.

B. Limitations of Simulation :

1. It does not generate optimal solutions. It is a trial-and-error approach that may produce different solutions in repeated runs.
2. Methods generally are not efficient.
3. It is a long complicated process to develop a model and expensive also.
4. Each solution model is unique and cannot be used for other similar problems.
5. It is descriptive process rather than optimization process.
6. It is difficult to quantify the variable.

C. Applications of Simulation :

1. Evaluating alternative investment opportunities and financial forecasting.
2. Testing an aircraft model in a wind tunnel.
3. It is used in banks to determine the number of tellers required to serve customers.
4. It is used to model hospitals, banks, educational institutions and urban systems.
5. Modelling, luggage handling in airports.

Que 5.33. What are different simulation models ? Explain.

Answer

Different simulation models are as follows :

a. Deterministic Model :

1. A deterministic model is used in that situation wherein the result is established straightforwardly from a series of condition.
2. In a situation wherein the cause-and-effect relationship is stochastically or randomly determined, the stochastic model is used.
3. A deterministic model has no stochastic elements and the entire input and output relation of the model is conclusively determined.
4. A dynamic model and a static model are included in the deterministic model.

b. Probabilistic Model :

1. Probabilistic modeling is any form of modeling that utilizes the presumed probability distribution of certain input assumptions to calculate the implied probability distribution for chosen output matrices.
2. This differs from a standard deterministic model, say a typical Excel spreadsheet, where we can change the values of input assumptions at random and see the impact of those changes on the output.
3. However we make only a limited effort to determine just how likely it is that the assumptions and therefore the outputs will change.

c. Static Model :

1. The model which does not consider the passage of time is known as a static model. For understanding vast and complex phenomenon there is a method wherein time is suppressed and the spatial existence substances or resources is comprehended as a distribution or layout problem at the specific time.
2. A static model is used when one attempts to look at the balance of variables in steady state rather than to understand behaviour under a transient state.
3. Equations of materials or energy balance and algebraic equations can be used as equations representing a static model.
4. Linear programming, non-linear programming, integer programming, etc. are the methods for finding a solution using a static model.

d. Dynamic Model :

1. All phenomenon in the natural world change with the passage of time, for modeling natural phenomenon and physical phenomenon, a dynamic model, which exhibits temporal change, can be used.
2. A differential equation forms the basis for expression of a dynamic model.
3. In order to understand a differential equation accurately and properly it is necessary to finely divide it temporally and spatially and the analyst is compelled to battle, with the memory capacity and computation time.
4. As a means for curtailing the memory capacity and computation time, various approximate solutions of differential equations have been developed.

Que 5.34. What is Monte-Carlo simulation ? Discuss in brief.

Answer

1. The Monte-Carlo method of simulation was developed by the two mathematician John Von Neumann and Stanislaw Ulam. The technique provided an approximate but quite workable solution to the problem.
2. The technique employs random numbers and is used to solve problems that involve probability and wherein physical experimentation is impracticable and formulation of mathematical model is impossible. It is a method of simulation of sampling technique.
3. The steps involved in carrying out Monte-Carlo simulation are :

Step 1. Select the measure of effectiveness (objective function) of the problem. It is either to be maximized or minimized. For example, it may be idle time of service facility in a queuing-problem or number of shortage or the total inventory cost in an inventory control problem.

Step 2. Identify the variables that affect the measure of effectiveness significantly. For example, number of service facilities in a queuing problem or demand, lead time and safety stock in inventory control problem.

Step 3. Determine the cumulative probability distribution of each variable selected in step 2. Plot these distributions with values of the variables along x -axis and cumulative probability values along the y -axis.

Step 4. Get a set of random numbers.

- Step 5.** Consider each random number as a decimal value of the cumulative probability distribution. Enter the cumulative distribution plot along the y -axis. Project this point horizontally till it meets the distribution curve. Then project the point of intersection down on the x -axis.
- Step 6.** Record the value (or values) generated in step 5. Substitute in the formula chosen for measure of effectiveness and find its simulated value.
- Step 7.** Repeat step 5 and 6 until sample is large enough to the satisfaction of the decision maker.





Overview of Industrial Engineering (2 Marks Questions)

1.1. Define production system.

Ans. Production system is a framework of activities within which the creation of value can occur.

1.2. Define productivity and formula to measure it.

Ans. Productivity is a ratio of actual output (production) to what is required to produce it (inputs).

$$\text{Productivity} = \frac{\text{Actual Output}}{\text{Actual Input}}$$

1.3. What are the factors affecting productivity.

Ans. Factors affecting productivity are as follows :

1. Human resources,
2. Technology and capital investment,
3. Government regulation,
4. Product and system design, and
5. Machinery and equipment.

1.4. What are the factors to be considered for selection of site ?

Ans. Factors to be considered for selection of site are as follows :

1. Raw materials availability.
2. Proximity to market.
3. Labour availability.
4. Transport and communication.
5. Energy (Fuel/Power).

1.5. What are the objectives of good plant layout ?

Ans. Objectives of good plant layout are as follows :

1. Integrate the production centres.
2. Reduce materials handling.
3. Effective space utilization.
4. Flexibility.
5. Worker convenience and job satisfaction.

1.6. What are the types of production system ?

Ans. Types of production system are as follows :

1. Mass production system,
2. Process production system,
3. Job production or project type production system, and
4. Batch production system.

1.7. Define intermittent and continuous production system.

Ans. Intermittent production system : In this system, the goods are manufactured specially to fulfill orders made by customers rather than for stock.

Continuous production system : In this system, the items are produced for the stocks and not for specific orders.

1.8. Differentiate between mass production and job production system.

Ans.

S. No.	Mass Production System	Job Production System
1.	In mass production system, items are produced in large amount.	In job production system, goods are produced according to customer's demand.
2.	For example : Newspapers and magazines etc.	For example : Ship building, dam construction etc.

1.9. Define FMS.

Ans. A flexible manufacturing system (FMS) is a highly automated GT machine cell. It consists of a group of processing workstations (usually CNC machine tools) interconnected by an automated material handling and storage system, and controlled by a distributed computer system.

1.10. What do you mean by material handling ?

Ans. Material handling is the art and science involving the movement, packaging and storing of substance in any form. It refers to the movement of materials from the store room to the machine and from one machine to the next during the process of manufacture.

1.11. Write the types of plant layout

Ans. Types of plant layout are as follows :

1. Process layout,
2. Product layout,
3. Combination of process and product, and
4. Fixed position layout.

1.12. Write any five important uses of productivity measurement ?

Ans. Five important uses of productivity measurement are as follows :

1. Productivity increases output.
2. Higher productivity helps to reduce cost per piece.
3. Low price increases demand of the product which in turn increases profit of the organization.
4. Higher profit enables organization to offer higher dividend for shareholders.
5. It increases export and increases foreign exchange reserves of a country.

1.13. What are the types of materials handling equipment ?

Ans. Types of material handling equipments are as follows :

1. Lifting and lowering devices.
2. Transporting devices.
3. Combination devices.

1.14. What are different types of productivity measurement ?

Ans. Types of productivity measurement are as follows :

1. Land productivity,
2. Material productivity,
3. Labour productivity,
4. Machine productivity, and
5. Capital productivity.

1.15. Define product liability.

Ans. Product liability refers to the liability of any or all parties along the chain of manufacture of any product for damage caused by that product.

1.16. What do you mean by operations management ?

Ans. Operations management may be defined as a systematic approach to address all the issues pertaining to the transformation process that converts some inputs into output that are useful and could fetch revenue to the organizations.

1.17. What is Group Technology (GT) ?

Ans. Group technology is a manufacturing philosophy in which similar parts are identified and grouped together to take advantage of their similarities in design and production.



2

UNIT

Production Planning and Control (2 Marks Questions)

2.1. Write the steps involved in production planning and control.

Ans. Steps involved in production planning and control are as follows :

1. Forecasting.
2. Order writing.
3. Product design.
4. Routing.
5. Loading and scheduling.
6. Machine loading.
7. Dispatching.

2.2. What do you mean by forecasting ?

Ans. Forecasting means estimation of type, quantity and quality of future work e.g. sales etc. Forecast represents a commitment on the part of the sales department and each of its divisions of expected sales. It becomes a goal against which the effectiveness of the sales department will be measured.

2.3. Define causal forecasting.

Ans. Causal forecasting assumes that the future is based on some underlying factor or factors.

2.4. What is regression analysis ?

Ans. Regression analysis enables us to determine the relationship between a variable of interest and one or more independent variables. For examples, consumption is a function of income.

2.5. What are the methods of aggregate scheduling ?

Ans. Methods of aggregate scheduling are as follows :

1. Graphical or charting methods.
2. Mathematical approaches.

2.6. Write the objectives of MRP.

Ans. Objectives of MRP are as follows :

1. Inventory reduction.
2. Avoid delays.

3. Realistic commitments.
4. Increased efficiency.

2.7. Define MRP.

Ans. Material requirements planning (MRP) is a computational technique that converts the master schedule for end products into a detailed schedule for the raw materials and components used in the end products.

2.8. What do you mean by MRP II ?

Ans. Manufacturing resource planning can be defined as a computer based system for planning, scheduling, and controlling the materials, resources, and supporting activities needed to meet the master production schedule.

2.9. Define network scheduling.

Ans. Network scheduling is a technique used for planning and scheduling large projects in the fields of construction, maintenance, fabrication, purchasing, computer system installation, research and development designs, etc.

2.10. Define critical path.

Ans. The sequence of critical activities in a network is called the critical path. The critical path is the longest path in the network from the starting event to ending event and defines the minimum time required to complete the project.

2.11. What are the main features of critical path ?

Ans. The critical path has two main features :

1. If the project has to be shortened, the some of the activities on that path must also be shortened. The application of additional resources on other activities will not give the desired result unless that critical path is shortened first.
2. The variation in actual performance from the expected activity duration time will be completely reflected in one to one fashion in the anticipated completion of the whole project.

2.12. What do you mean by project evaluation and review technique (PERT) ?

Ans. PERT is the basic network technique which includes planning, monitoring and control of projects. It is applied in planning and control of complex set of tasks, function and relationships.

2.13. What is optimistic time ?

Ans. Optimistic time is the shortest possible time in which the activity can be finished. It assumes that everything goes very well. It is denoted by t_0 .

2.14. Define pessimistic time.

Ans. Pessimistic time represents the longest time, the activity could take to finish. It is the worst time estimate and denotes that time which activity would take if bad luck was faced.

2.15. What are the requirements for application of PERT ?

Ans. Requirements for application of PERT are as follows :

1. PERT is applicable for project management which is basically new or of number repetitive nature.
2. PERT is usually applicable to very large, complex, customized projects that consist of many inter-related activities to be performed either concurrently or sequentially.



3

UNIT

Engineering Economy and Inventory Control (2 Marks Questions)

3.1. Define depreciation.

Ans. Depreciation is a measure of the wearing out, consumption or other loss of value of depreciable asset arising from use, effluxion of time or obsolescence through technology and market changes.

3.2. What are the factors affecting depreciation.

Ans. Factors affecting depreciation are as follows :

1. Acquisition cost.
2. Estimated life.
3. Estimated salvage value.
4. Selection of depreciation method.

3.3. Write the assumptions in break-even analysis.

Ans. Assumptions in break-even analysis are as follows :

1. All the units produced are sold in the market.
2. Fixed cost remains fixed for any production volume.
3. Variable cost increase is linear.
4. Selling prices will remain constant at all sales levels.
5. Production and sales quantities are equal.

3.4. What do you mean by inventory control ?

Ans. Inventory control means making the desired items, of required quality and in scientifically determined quantity to meet the production demands, available to various departments when needed.

3.5. What is ABC analysis ?

Ans. ABC analysis is a way of categorizing the material on the basis of the quantity of consumption and their relative values. In ABC (Always Better Control) inventory management technique A category consists of high-priced inventory which may be less in number but are very expensive.

3.6. Why does queuing problem arise ?

Ans. Queuing problems arise because :

1. There is too much demand on the facilities so that we say there is an excess of waiting time or inadequate number of service facilities.
2. There is too less demand, in which case there is too much idle facility time or too many facilities.

3.7. Describe the queuing system.

Ans. A queuing system can be completely described by :

1. The input,
2. The service mechanism,
3. The queue discipline, and
4. Customer's behaviour.

3.8. Define the following terms :

- a. **Transient state.**
- b. **Steady state.**

Ans.

- a. **Transient State :** A system is said to be in transient state when its operating characteristics are dependent on time.
- b. **Steady State :** A steady state condition is said to prevail when the behaviour of the system becomes independent of time.

3.9. Give the operating characteristics of a queuing system.

Ans. Some of the operational characteristics of a queuing system are as follows :

1. Expected number of customers in the system.
2. Expected number of customers in the queue.
3. Expected waiting time in the system.
4. Expected waiting time in queue.
5. The server utilization factor.

3.10. Define the following factors :

- a. **Queue length.**
- b. **System length.**

Ans.

- a. **Queue Length :** The average number of customers in the queue waiting to get service. This excludes the customers being served.
- b. **System Length :** The average number of customers in the system including those waiting as well as those being served.

3.11. Define the following factors :

- a. **Waiting time in the queue.**
- b. **Total time in the system.**

Ans.

- a. **Waiting Time in the Queue :** The average time for which a customer has to wait in the queue to get service.

- b. Total Time in the System :** The average total time spent by a customer in the system from the moment he arrives till he leaves the system. It is taken to be the waiting time plus the service time.

3.12. What are the limitations of queuing model ?

Ans. Limitations of queuing model are as follows :

1. The waiting space for the customers is usually limited.
2. The arrival rate may be state dependent.
3. The population of customers may not be infinite and the queuing discipline may not be first come, first served.

3.13. In which situation the queuing theory is best suited ?

Ans. Queuing theory is applied best in the situations where there is only one channel of arrival at random and the service time is constant.

3.14. Give the applications of queuing models.

Ans. Applications of queuing models are as follows :

1. Scheduling of mechanical transport fleets.
2. Scheduling distribution of scarce war material.
3. Scheduling of jobs in production control.
4. Minimizing of congestion due to traffic delay at toll booths.
5. Solution of inventory control problems.



4

UNIT

Work System Design (2 Marks Questions)

4.1. Define work study.

Ans. Work study is a technique used to examine the activities done by human being and investigate those factors that affect the accuracy and efficiency of the workers. Work study helps to complete a particular work or job in the best possible way.

4.2. What is the scope of work study ?

Ans. Work study finds applications in industries, marketing (sales and distribution), offices stores and warehouses, material handling, design, building construction, transport, hospital, army and agriculture etc.

4.3. Define method study.

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

4.4. Define work measurement.

Ans. Work measurement is concerned with elimination of ineffective time and establishment of time standards for a job. Work measurement is a technique to establish the time for a qualified worker to carry out a specified job at a definite level of performance.

4.5. What are the objectives of motion study ?

Ans. Objectives of motion study are as follows :

1. Removal of unwanted motions.
2. Increase the efficiency of all activities.
3. Improve the proper motion of activities.
4. Enhancing the material handling process.

4.6. What do you mean by standard time ?

Ans. Standard time is the total time in which the job should be completed at standard performance.

4.7. Define the term ergonomics.

Ans. Ergonomics is defined as the relationship between man and machine and the application of anatomical, physiological and psychological principles to solve the problems arising from man-machine relationship.

4.8. What are the methods of job evaluation ?

Ans. Methods of job evaluation are as follows :

1. Ranking method.
2. Job classification/grading method.
3. Factor comparison.

4.9. Define merit rating.

Ans. Merit rating is systematic evaluation of an employee's performance on the job in terms of the job requirements and identifying the suitability of the candidate for jobs of higher responsibility.

4.10. What are the objectives of merit rating ?

Ans. Objectives of merit rating are as follows :

1. Merit rating improves productivity and reduces hostility between employer and employee.
2. Points out individual strengths and weaknesses.
3. Promotes competitiveness and a desire for improvement.
4. Enables management to determine training needs.

4.11. What is the importance of wages and incentives ?

Ans. Wages and incentives affect management-employee relation. It plays an important role in maintaining peace, increasing production rate and economic efficiency.

4.12. What is standardization ?

Ans. Standardization is temporary crystallization of the best acceptable solution to a recurring problem, formulated in a scientific and systematic fashion by pooling the knowledge of all those who are concerned with the problem and is subjected to review and revision by common consent, and one should comply to it.

4.13. Define simplification.

Ans. Simplification is the process of reducing the variety of products manufactured (known as variety reduction). It is concerned with the reduction of product range, assemblies, parts, materials and design.

4.14. What is diversification ?

Ans. Diversification means additions of new products or introduction to established product into new market. This tends to increase complexity of the methods of manufacturing, because, sometimes consumers like to have variety in type, size colour and quality of product being manufactured.

4.15. Discuss value analysis.

Ans. Value analysis (VA) is concerned with existing products. It involves a current product being analyzed and evaluated by a team, to reduce costs, improve product function or both.





Operational Analysis (2 Marks Questions)

5.1. Define LPP.

Ans. The general LPP calls for optimizing a linear function of variables called the objective function subject to a set of linear equations and or inequalities called the constraints or restrictions.

5.2. What are the fundamental conditions of simple method ?

Ans. The basis of the simple method consists of two fundamental conditions :

1. The feasibility condition, and
2. The optimality condition.

5.3. What is basic feasible solution ?

Ans. It is a basic solution that also satisfies the non-negativity restrictions. All variables in a basic feasible solution are ≥ 0 . Every basic feasible solution of a problem is an extreme point of the convex set of feasible solutions and every extreme point is a basic feasible solution of the set of constraints.

5.4. What is sensitivity analysis ?

Ans. The investigation that deals with changes in the optimal solution due to changes in the parameter (a_{ij} , b_i and c_j) is called sensitivity analysis.

5.5. Define duality.

Ans. Every linear programming problem has associated with it's another linear programming problem. The original problem can be considered the primal while the remaining problem it's dual.

5.6. What do you mean by assignment problem ?

Ans. It is a special case of the transportation problem in which the objective is to assign a number of resources to the equal number of activities at a minimum cost.

5.7. Explain the reduced matrix method ?

Ans. Reduce matrix method is based on the concept of opportunity cost. Opportunity cost show the relative penalties associated with assignment of resources to an activity as opposed to making the best or least cost assignment. If we can reduce the cost matrix to the extent of having at least one zero in each row and each column, then it will be possible to make optimal assignment.

5.8. Write the methods of solving assignment problem.

Ans. An assignment problem can be solved using the following four methods :

1. Complete enumeration method,
2. Transportation method,
3. Simplex method, and
4. Hungarian method.

5.9. Why is an activity assigned to a resource with zero opportunity cost ?

Ans. While solving an assignment to a resource with zero opportunity cost because the objective is to minimize total cost of assignment.

5.10. How is a maximization assignment problem transformed into a minimization problem ?

Ans. Maximization assignment problem is transformed into a minimization problem by subtracting each element of the profit matrix from the highest element of the matrix.

5.11. What is the purpose of a dummy row or column in an assignment problem ?

Ans. The purpose of a dummy row or column in an assignment problem is to obtain balance between total activities and total resources.

5.12. Define transportation problem.

Ans. The transportation problem is to transport various amounts of a single homogeneous commodity that are initially stored at various origins, to different destinations in such a way that the total transportation cost is minimum.

5.13. What are the methods of finding an optimal solution ?

Ans. Methods of finding an optimal solution of the transportation problem will consist of two main steps :

1. To find an initial basic feasible solution.
2. To obtain an optimal solution by making successive improvements to initial basic feasible solution until no further decrease in the transportation cost is possible.

5.14. What are the methods of finding an initial basic feasible solution in transportation problem ?

Ans. Methods of finding an initial basic feasible solution in transportation problem are as follows :

1. North-west corner method,
2. Least-cost method, and
3. Vogel's approximation method.

5.15. Define simulation.

Ans. Simulation is a representation of reality through the use of a model or other device which will react in the same manner as reality under a given set of conditions.

5.16. What are the types of simulation ?

Ans. Simulation is mainly of two types :

1. Analogue simulation, and
2. Computer simulation.

5.17. Give the advantages of simulation.

Ans. Advantages of simulation are as follows :

1. Simulation methods are easier to apply than pure analytical methods.
2. The knowledge of a system obtained in designing and conducting the simulation.
3. It enables us to assess the possible risks involved in a new policy before actually implementing it.

5.18. Give any three limitations of simulation.

Ans. Limitations of simulation are as follows :

1. Simulation generates a way of evaluating solutions but it does not generate the solution techniques.
2. Not all situations can be evaluated using simulation. Only simulations involving uncertainty are considered.
3. Simulation is a time-consuming exercise.





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