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## PART - A

## 2 Marks Questions

1.  
Sol. Johnson's Rule explain about the sequencing of jobs on two machines.
2.  
Sol. It is a group or combination of interrelated activities that must be executed in certain fixed order before the entire task is completed
3.  
Sol. It is a recognizable part of a project which consume time and resources for its completion and it may involve physical and useful work.
4.  
Sol. An activity which is used to show the dependency logic or relationship of one activity over the other but does not consume any time or resources for its completion in termed as dummy activity.
5.  
Sol. When activity other than the final activity doesnot have any successive activity. The situation is called as dangling such activity should be connected to the last event of network diagram
6.  
Sol. It is the maximum time consuming path from the first event to last event in a network diagram.
7.  
Sol. It is that part of total float which can be used without affecting the float of succeeding activity
8.  
Sol. It is the extension of critical path method that consider a compromise between the time and cost required to complete a project
9.  
Sol. Forecasting can be termed as prediction of future or demand of a particular product. It is a human judgement technique
10.  
Sol. In this method a panel of expert are asked sequential question in which the response to one question is used to produce next. It is step by step procedure in which information available to other expert and final forecast is obtained by common opinion of all the expert

11.

Sol.

In this method the work of survey is assigned to external marketing agency and the purpose of research is to collect information regarding the demand of a product. The details about various factors which influence the demand like customer location, occupation, income, quantity, quality etc. are related to get the forecast

12.

Sol.

Responsiveness indicated that forecast has fluctuation or swinging pattern. It is preferred for new product and for that number of periods kept small stability means that the forecast pattern is flat, smooth or has less fluctuation, it is preferred for old existing product

13.

Sol.

The aim of assembly line is to improve different facilities and equipment in such a manner that all the work stations are given on an average equal work load and the ideal time is minimized

14.

Sol.

It is the time required to complete work element assigned in a work station

15.

Sol.

- (i) Smooth flow of production
- (ii) Lower material handling cost
- (iii) Lesser work in process
- (iv) Optimum space utilization

16.

Sol.

Fixed position layout is a design for floor plan of a plant in which product remains at fixed position while the work, machine moves to it as needed. Products that are impossible to move like ships, airplanes and construction projects are manufactured in fixed position layout

17.

Sol.

It is a set of techniques developed to divide a job into smaller parts followed by its rearrangement to make it more effective or productive

18.

Sol.

Select > Record > Examine > Develop > Install > Maintain

19.

Sol.

These charts record all the activities sequence wise along with time, distance and additional remarks they are of three types

- (i) Material type      (ii) Machine type
- (iii) Man type

20.

Sol.

It is used to study those operations which are very fast, very short duration and repeated several no of times.

21.

Sol.

It is a time required to complete the job taking all the uncertainty related to the production system into account

22.

Sol.

It is the amount of time for which the job that is to be assembled remains between two successive product coming out from the assembly line

23.

Sol.

It is the ratio of total ideal time of the job for assembly line to the total time spend by the job on the assembly line

$$B.D = 1 - \frac{TWC}{\eta T_c}$$

24.

Sol.

Plant layout is the arrangement of machines, work areas and service area with in a factory

OR

Plant layout involves the development of physical relationship among building, equipment and production operations, which will enable the manufacturing process

25.

Sol.

There are three types of layout that are most commonly used

(i) Product layout

(ii) Process layout

(iii) Fixed position layout

26.

Sol.

Process layout is a design for floorplan of a plant which aims to improve efficiency by arranging equipment according to its function. The production line should ideally be designed to eliminate waste in material flows, inventory handling and management

27.

Sol.

This analysis is most widely used in cost volume profit analysis. It provides a relationship between revenues and cost will respect to volume of sales

28.

Sol.

It is the point in cost volume chart at which cost and revenue are in equilibrium



29.

Sol.

The excess of actual or budgeted sales over the break even sales is called margin of safety  
 $(MOS)_{sales} = \text{Actual sales} - \text{BEP sales}$

30.

Sol.

Safety of the firm

31.

Sol.

- (i) Difficult to separate cost into fixed and variable component
- (ii) It is difficult to use for a multi product firm
- (iii) It cannot be used for long term planning

32.

Sol.

It is the tool used for customer satisfaction i.e. this tool is used to find out service pattern so that maximum utilisation of server and minimum waiting time for customer takes place.

33.

Sol.

It is the average number of customers in the queue waiting to get service. This excludes the customer being served.

34.

Sol.

It is a long term forecasting method.

35.

Sol.

**Balking customer :-** If he will not join the queue

**Raneging customer :-** If the customer joins and loses patience and leaves it after some time

**Jockeying customer :-** If customer moves from one queue to other queue to get fast service

36.

Sol.

It is the proportion of time a server actually spends with the customers

37.

Sol.

The rate at which one channel can perform the service i.e. the number of customer being served per unit time is called service rate. It follows exponential distribution means most of the customer occupy mean time but some will take long time

38.

Sol.

The rate at which customers arrive to be serviced i.e. number of customer arriving per unit time is called arrival rate

39.

Sol.

The arriving unit that requires some service to be performed the customer may be person, machines, vehicles, parts etc.

40.

Sol.

Kendall's Notation is a tool to represent queuing model and it is expressed as

$(a/b/c) : (d/e/f)$

$a \rightarrow$  Arrival rate

$b \rightarrow$  Service rate

$c \rightarrow$  Number of parallel service channels

$d \rightarrow$  Service discipline

$e \rightarrow$  maximum number of customers allowed in the system

$f \rightarrow$  calling population

41.

Sol.

$$W_s = \frac{1}{\mu - \lambda}$$

$\mu \rightarrow$  service rate

$\lambda \rightarrow$  customer arrival rate

42.

Sol.

Linear programming deals with the optimization (maximization or minimization) of a function of variables known as objective function subject to a set of linear equation or inequalities known as constraint

43.

Sol.

In any organisation (big or small) there is a limitation of resource (man, machine, money) the organisation want maximum profit or minimum cost with limited organisation want resources LPP provide best way for them to satisfy the resources and its function

44.

Sol.

- (i) Proportionality      (ii) Additivity
- (iii) Continuity        (iv) Certainty
- (v) Finite choices

45.

Sol.

- (1) In industrial application
  - (i) Product mix problems
  - (ii) Production scheduling problem
  - (iii) Assembly line balancing
- (2) In management application
  - (i) Portfolio selection problem
  - (ii) Transportation problem
- (3) In Diet problem
- (4) Agriculture problem

46.

Sol.

Two method

(i) Graphical method

(ii) Simplex method



47.

Sol.

Graphical method can be used only for two variable only

48.

Sol.

Those variable for which the first basic feasible solution is obtained for the LP is known as basic variable

49.

Sol.

Optimal solution is that solution which is obtained from basic feasible solution for the betterment of current solution and relocate or adjust current basic variables.

50.

Sol.

It ensures that if the starting solution is basic feasible, only BFS will be obtained during computation.

51.

Sol.

If some of the basic variables in solution are zero, the solution is called degenerate solution

52.

Sol.

If the value of the objective function can be increased or decreased infinitely, the solution is called unbounded solution.

53.

Sol.

Inventory is the stock of any item or resources that are used in any organisation

OR

It may be defined as stock in hand at a given time and they can be used later

54.

Sol.

- (i) Purchase cost
- (ii) Ordering or setup cost
- (iii) Holding or carrying cost
- (iv) Shortage or back order cost or stockout cost

55.

Sol.

It is the cost associated to produce units internally. It is associated with bringing production system again into play is called set up cost

56.

Sol.

Shortage simply means absence of inventory items and the cost associated with not serving the customer is called shortage cost.

57.

Sol.

Those inventory items which are in transportation can not provide service and that inventory item is called transit or pipeline inventory



58.

Sol.

It is the minimum amount of inventory item that has been kept for protecting against the fluctuation in demand and lead time.

59.

Sol.

It is used when there is a adverse situation like variation in lead time or demand during lead time

60.

Sol.

These inventory items are build up to meet anticipated demand in future while like big selling forecast, government policy, price hike, strike, shutdown etc

61.

Sol.

The demand of these item is directly related or link to demand any other item, usually of a higher level of which it become parts.

62.

Sol.

Two types of inventory review system are majorly used  
 (1) Q-system or fixed order sytem or Two bin system  
 (2) P-system or fixed period system or periodic review system  
 → A combined is used which is called ss system

63.

Sol.

It is used in two bin system where a new lot is ordered when the units in larger bin gets over

64.

Sol.

In this system inventory level is review after a fixed point of time and a fresh order of variable quantity is placed at the point

65.

Sol.

Two types of inventory model are present  
 (1) Deterministic (2) Probablistic  
 (1) Deterministic :- In these model demand rate and lead time remains fixed and constant i.e. no fluctuation this is the reason that we need not to carry safety stock  
 (2) Probablistic :- These model represent the real world condition where is there uncertainty of demand rate and lead time.

66.

Sol.

If represent the order quantity of a lot to balance in holding cost and ordering cost in order to get minimum cost of inventory

67.

Sol.

$$Q^* = \sqrt{\frac{2DC_0}{C_h}} \sqrt{\frac{C_b + C_h}{C_b}}$$



68.

Sol.

In build up model inventory is build up gradually rather than instantaneous replacement upto production time inventory are building up along with consumption with ( $p > d$ ) i.e. higher production

rate in comparasion to demand rate so max inventory will be  $Q_m = \left( \frac{p-d}{p} \right) Q$

where  $Q$  = Total inventory for a cycle

$p$  - production rate

$d$  - demand rate

69.

Sol.

$$S.C. = \frac{S^2}{2Q} \cdot C_b$$

70.

Sol.

Requirement of safety stock take place only when either lead time increases or demand rate increases after re order level. This increases the chance or probability to stock out. That is why higher safety stock is needed in probablistic model.

71.

Sol.

- (i) When the demand rate and lead time variation are more and fluctuating
- (ii) When holding cost is very less
- (iii) When stockout cost is very high
- (iv) No. of orders are more

72.

Sol.

It is assumed to follow normal distribution with mean ( $LT \times d$ ) and  $\sigma$  as standard deviation

73.

Sol.

Sequencing is the arrangement of different number of jobs on the machine in such a manner that ideal time of a machine is minimum and utilization will be optimised.

74.

Sol.

It is essential for smooth flow material and effective utilization of resources (Man, Machine etc)

75.

Sol.

It is the time from some starting point untill that particular job is completed

76.

Sol.

It is the time from when processing being on the first job in the set until the last job is completed.

77.

Sol.

**Trend line:** The line of best fit to represent the future demand using past data in called. Trend line. The square sum of error of this is zero

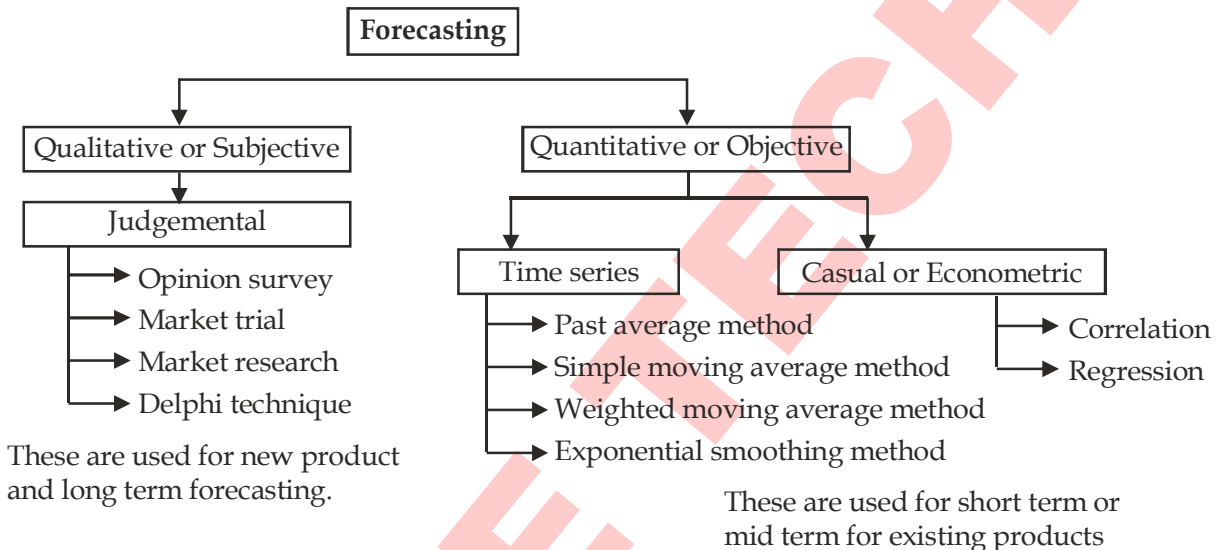


78.

**Sol. Purpose (or) need of Sales forecasting**

- It determines the volume of production and the production rate.
- It forms basis for production budget, labour budget, material budget, etc.
- It suggests the need for plant expansion.
- It emphasizes the need for product research development.
- It suggests the need for changes in production methods.
- It establishes pricing policies.
- It helps deciding the extent of advertising, product distribution, etc.

79.

**Sol.** Forecasting methods are classified into

80.

**Sol.** After drawing the network in a logical sequence, every event is assigned a number. The number sequence must be such that it reflect the flow of the network. There are following rules for event numbering:

1. Event numbers should be unique.
2. Event numbering should be carried out on a sequential basis from left to right.
3. The initial event which has all outgoing arrows with no incoming arrow is numbered 0 or 1.
4. The head of an arrow should always bear a number higher than the one assigned at the tail of the arrow.
5. Gaps should be left in the sequence of event numbering to accommodate subsequent inclusion of activities, if necessary.

81.

**Sol.** The material requirement planning has following inputs and outputs:

Inputs:

1. master production schedule
2. bill of material
3. inventory records and inventory requirement

Outputs:

1. planned order schedule
2. order releases
3. changes in schedule
4. inventory transactions



Name 4 basic ways of establishing a time standard.

- Work sampling
- Stop watch study
- Predetermined Time Standards (PTS)
- Analytical estimating

82.

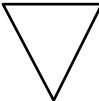
**Sol.** **Value Engineering:** Value engineering is the application of the concepts of value analysis at the design or premanufacture stage of the component parts with a view to cut down the unnecessary costs, without impairing the function or utility of the product.

**Conditions that are conducive to take up VA/VE study are:**

- Scope for the simplification of the product
- Scope to use new cheaper and better materials
- Scope to modify and improve product design
- Scope to use efficient process
- Scope to reduce the product cost
- Scope to increase the utility of the product by economical means
- Scope to save money or to increase the profits.

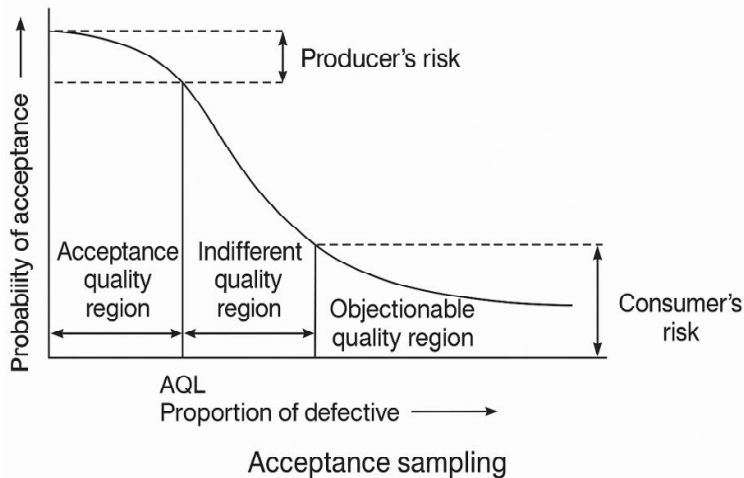
83.

**Sol.** Give the symbols, activity names used in method study for charting of the processes.

| S. No. | Activity                   | Symbol                                                                              |
|--------|----------------------------|-------------------------------------------------------------------------------------|
| 1.     | Operation                  |    |
| 2.     | Inspection                 |   |
| 3.     | Transport                  |  |
| 4.     | Temporary storage or delay |  |
| 5.     | Permanent storage          |  |

84.

**Sol.** Operating Characteristic Curve (OCC) is a graph of fraction defective in a lot against the probability of acceptance.



85.

**Sol.** Explain the term "Industrial Relations".

More specially, Industrial Relations is concerned with the systems, rules and procedures used by unions and employers to determine the reward for effort and other conditions of employment, to protect the interests of the employed and their employers and to regulate the ways in which employers treat their employees.

86.

**Sol.** Areas of IR are:

- (1) Collective Bargaining.
- (2) Role of management, union and government.
- (3) Resolution of industrial dispute.
- (4) Individual grievance and disciplinary policy.
- (5) Labour legislation.
- (6) Industrial relations training.

87.

**Sol.** Importance of IR:

- To protect the interest of workers and improve their economic conditions.
- To protect the rights of managers.
- To regulate the ways in which employers treat their employees.
- To increase productivity.

88.

**Sol.** Put simply, Industry 4.0 is an initiative to revolutionise the manufacturing and engineering sector by combining the digital world and that of industrial production to create "smart" manufacturing facilities. Some of the expected benefits include resource **productivity and efficiencies**, along with greater flexibility in creating highly personalised or configured products on a mass scale. Industry 4.0 refers to the promise of connecting the digital and the physical worlds through smart factories that contain cyber-physical systems. The term includes many different technologies, applications, and concepts which is why many people are often confused as to what exactly is included under the umbrella of "Industry 4.0".

89.

**Sol.** 3.0 vs 4.0 The main differences between factories of the past - even automated ones - and the most technologically advanced factories of today is the concept of connectivity. In a Data-Driven Manufacturing environment, every piece of equipment and every industrial machine is transformed into a node on the corporate network. On a more granular level, Data-Driven Manufacturing enables real-time machine-level monitoring, giving manufacturers a previously unavailable view of machine health. It also enables manufacturers to become proactive in terms of their machine upkeep and repairs, reducing downtime due to mechanical failures and problems.



90.

**Sol.** The manufacturing industry has always been driven by the pursuit of lean and more efficient processes. In today's fast-paced world, where consumers demand faster, cheaper, and higher-quality products, manufacturers are constantly challenged to improve their production processes. They strive to achieve the highest throughput, lowest cost, minimal material usage, and fastest cycle times. Once manufacturers have mastered the art of creating efficient processes, they don't stop there. They push themselves further through continuous improvement.

However, the problem is that continuous improvement has become the norm. Everyone is doing it, which means it no longer provides a competitive advantage. If you truly want to stand out and gain an edge over your competitors, you need to do more than what everyone else is doing. This is where Industry 4.0 solutions come into play. By implementing these advanced technologies and practices, you can take your operations to a whole new level. Another motivator is that with rising energy costs and resource scarcity, we have a responsibility to future generations to create as efficient processes as possible, next to reducing waste.

91.

**Sol. Lead time:**

- Lead time in inventory management is the amount of time between when a purchase order is placed to replenish products and when the order is received in the warehouse.
- Order lead times can vary between suppliers; the more suppliers involved in the chain, the longer the lead time is likely to be
- Companies review lead time in manufacturing, supply chain management, and project management during pre-processing, processing, and post-processing stages.
- By comparing results against established benchmarks, they can determine where inefficiencies exist. Reducing lead time can streamline operations and improve productivity, increasing output, and revenue.
- By contrast, longer lead times negatively affect sales and manufacturing processes
- To calculate the lead time we need to find the supply delay and reordering delay.

92.

**Sol. Differential Piece rate system:**

- The underlying principle of this system is to penalize a slow worker by paying him a low piece rate for low production and to reward an efficient worker by giving him a higher piece rate for higher production.
- To encourage the workers to complete the work within the standard time, Taylor advocated two-piece rates, so that if a worker performs the work within or less than the standard time, he is paid a higher piece rate, and if he does not complete the work within the standard time, he is given a lower piece rate.

93.

**Sol. Straight piece rate system:**

- Under the straight piece rate plan workers are paid based on their output.
- For example, if the piece rate is Rs. 5 per piece of the product, then a worker who turns out 50 pieces/day earns Rs. 250 ( $\text{Rs. } 5 \times 50$ ) as his wage for that day. Whereas, another employee who produces 40 pieces/day earns Rs. 200 ( $\text{Rs. } 5 \times 40$  pieces). Hence a fast worker earns more compared to a slow worker.
- It Motivates the workers to increase their output and improve productivity.
- However, there is no guaranteed minimum wage. This makes workers insecure. There is a great disparity in earnings between slow and fast workers.
- Quality of production may suffer as the workers concentrate on quantity.
- Enforced idleness like electricity failure or machine breakdown, adversely affects the earnings of workers.

94.

**Sol. Hasley Plan:**

- Halsey premium plan is a simple combination of time and speed bases of payment.
- Under this plan, a minimum time wage is guaranteed to every worker.

- A standard time is fixed for the completion of a job. If a worker performs his job in less than the standard time, he is given a bonus. But there is no penalty for performing the job in more than the standard time fixed.
- The slow worker is paid the time wages and the efficient worker is paid some bonus in addition to the time wages. The bonus is in the proportion of the wages which he could have earned during the time saved.

95.

**Sol. Rowan Plan:**

- The Rowan plan is a modification of the Halsey plan.
- It also guarantees the minimum time wage and does not penalize a slow worker. A standard time is fixed for the completion of a job and a bonus is paid to a worker on the basis of time saved. Here, the bonus is that proportion of the wages for the time taken which the time saved bears to the standard time.

96.

**Sol. Micromotion study:**

- It is used for graphical presentation of many repetitive operations of short cycles like component assembly, packaging, inspection, separation of mixed jobs, which involve quick movements of the hand.
- In certain types of operations like pick and place objects, a detailed study of such operations can be carried out.
- Micromotion study involves 16 fundamental hand motions.
- "SIMO" stands for Simultaneous-Motion Cycle Chart.
- It is one of the micromotion studies devised by Gilbreth and it presents graphically the separable steps of each pertinent limb of the operator under study.
- It is an extremely detailed left and right-hand operation chart.
- SIMO chart records simultaneously the different therbligs performed by different parts of the body of one more operator on a common time scale.

97.

**Sol. Three key Operations Research (OR) models are:**

Linear Programming, which optimizes resource allocation under linear constraints;  
Queuing Theory, used to analyze waiting lines and server performance; and  
Simulation, which replicates complex systems to evaluate different scenarios without real-world experimentation



## PART - B

## 5 Marks Questions

98.

Sol.

## Comparison between Private Company and Public Company

| Sr. No. | Points                   | Private Company                                                                                                                                                                         | Public Company                                                        |
|---------|--------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------|
| 1.      | Meaning                  | A Private Limited Company is a company which by its articles, restricts the right to transfer share, limits the maximum number of members to 200 and prohibits the issue of prospectus. | A Public Company means a company, which is not a Private Company.     |
| 2.      | Name of the company      | Name of the company must end with the word 'Private Limited'.                                                                                                                           | Name of the company must end with the word 'Limited'.                 |
| 3.      | Number of the members    | There are minimum 2 members. Maximum members are 200.                                                                                                                                   | There are minimum 7 members. Maximum members are unlimited.           |
| 4.      | Transfer of shares       | Shares of the company are not freely transferable.                                                                                                                                      | Shares of the company are freely transferable.                        |
| 5.      | Issues of prospectus     | The company cannot issue prospectus. Statement in lieu of prospectus is issued.                                                                                                         | The company has to issue prospectus compulsorily.                     |
| 6.      | Number of directors      | Minimum 2 Directors are needed in a Private Limited Company.                                                                                                                            | Minimum 3 Directors are needed in a Public Limited Company.           |
| 7.      | Statutory of             | A Private Limited Company need not hold a Statutory Meeting.                                                                                                                            | A Public Limited Company must hold a Statutory Meeting                |
| 8.      | Capital                  | Minimum paid up capital is one lakh rupees.                                                                                                                                             | Minimum paid up capital is five lakh rupees.                          |
| 9.      | Commencement of business | The business can be started after getting 'Incorporation Certificate'.                                                                                                                  | The business can be started after getting 'Commencement Certificate'. |



99.

Sol. **Differences between Product and Process Layouts**

| Product Layout                                                 | Process Layout                                                              |
|----------------------------------------------------------------|-----------------------------------------------------------------------------|
| There is sequential arrangement of machines as per operations. | Functional arrangement of machines as per nature of operations of machines. |
| This is used for mass and continuous type of production.       | This is used for job-shop and batch production.                             |
| Products produced are standard and made to stock.              | The product produced is general and made to order.                          |
| This is used for stable and high demand products.              | This is used for the variable demand product.                               |
| Special-purpose machines are used.                             | General-purpose machines are used.                                          |
| Limited or semi-skilled people may be employed.                | High and cross-functional skilled people are employed.                      |
| Materials and men move on a fixed path.                        | Materials and men move on a variable path.                                  |
| This layout is highly efficient and productive.                | This layout is highly flexible.                                             |

100.

Sol. **Objectives of Plant Layout**

The objectives of plant layout are to:

1. utilize the available space effectively.
2. ensure smooth flow of materials.
3. improve the productivity.
4. reduce material-handling cost.
5. provide safety.
6. utilize labour effectively.
7. provide flexibility in operation.
8. provide easy supervision and control.
9. provide easy maintenance.
10. facilitate coordination and face-to-face communication.
11. reduce manufacturing cycle time or customer service time.

101.

Sol. **Product Layout**

In product layout, the machines are arranged according to the sequence of operations on a product. This is suitable for only mass or continuous production due to the requirement of high productivity. This layout is used in refinery, thermal power plant, chemical or fertilizer industry, etc. All the machines are arranged in a line as shown in Figure.

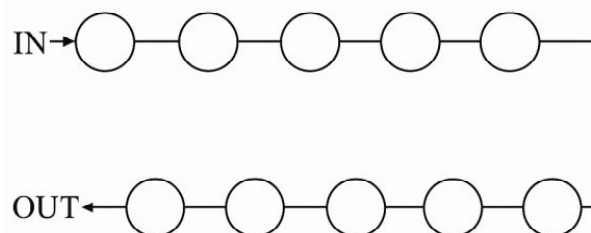


Fig.- Machines arrangement in product layout

There are many advantages and disadvantages of product layout as discussed below:

**Advantages**

1. It reduces material-handling time and hence the material-handling cost.
2. It increases the productivity due to ease of automation of the processes.
3. It reduces the manufacturing time.
4. It simplifies production planning and control systems.
5. It simplifies tasks, enabling unskilled workers to learn a task quickly.
6. It is more suitable to make to stock.

**Disadvantages**

1. It has poor flexibility in accommodation of production of new product.
2. Special-purpose equipment and duplication is required to minimize the time of completion of the operations.
3. A breakdown of one machine or absence of one operator may stop the entire line of production.
4. To prevent the production breakdown, there is requirement of high work-in-process inventory.
5. Workers may become bored by the endless repetition of similar jobs.
6. It is less suitable to make to order.

102.

**Sol. Facility location methods:** The following methods are used for plant location:

1. Factor-rating method
2. Transportation method for linear programming
3. Centroid method
4. Cost-volume-profit ratio/Break-even analysis

**Cost-Volume-Profit Ratio/Break-Even Analysis**

In this method, it is assumed that fixed cost and variable cost vary from location to location. Thus, the total cost is a function of volume. It is decided that which location involves minimum cost for a fixed volume of production. For example, three locations A, B and C are shown in Figure with a total cost and volume. It is observed from Figure that for less than or equal to volume  $X_1$  location A is profitable; between  $X_1$  and  $X_3$  volume location B is profitable; and for more than  $X_3$  volume location C is profitable.

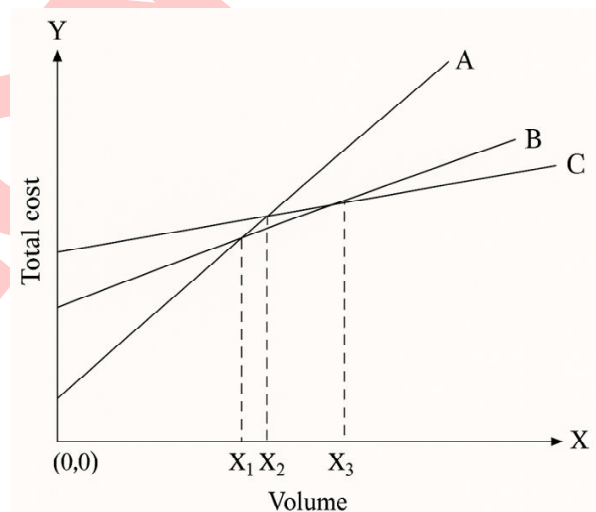


Fig.- Cost-volume-profit ratio for plant location

103.

**Sol.** There are following advantages and disadvantages of process layout:

**Advantages**

1. It is more flexible compared to product layout as equipment and personnel can be used for any product.
2. Investment required is less as duplication is not necessary unless volume is large.
3. Supervisors and workers get exposure of cross-functional skills.
4. Changing work nature creates interest among the workers and makes work more satisfying for the people who prefer variety.
5. This layout is more suitable for make to order or smaller volume of production.

**Disadvantages**

1. It requires highly skilled workers.
2. Backtracking and long movements in the handling of materials minimize the efficiency and increase the material-handling time and cost.
3. Waiting time is more in process layout.
4. Production planning and control is complex in comparison to product layout.
5. Workers' wages are higher due to involvement of highly skilled workers.
6. Due to frequent changes in the nature of the job, productivity becomes low.

104.

**Sol.** The advantages and disadvantages of group layout are enumerated as follows:

**Advantages**

1. The control required is reduced.
2. Material handling is reduced due to the formation of special cell for the individual part family.
3. Set-up time is reduced due to use of the automation process to search the suitable part family for new products.
4. In-process inventory is reduced.
5. Due to mixed properties of product and process layout, operator's expertise increases.
6. Due to requirement of better coordination among the different cells, human relations improve.

**Disadvantages**

1. Shop flexibility is reduced.
2. Machine utilization is also reduced compared to product layout.
3. Higher skilled person in each cell is required.
4. The cell concept leads to unbalanced workload on machines.

105.

**Sol.** The advantages and disadvantages of fixed position layout are as follows:

**Advantages**

1. It reduces the movement of work items and minimizes damage or cost of handling.
2. There is no problem like rearrangement of a machine or reassignment of jobs to workers.

**Disadvantages**

1. Skilled and versatile workers are required because same workers are involved in more than one operation.
2. The poor availability of necessary combination of skills may increase the wage.
3. Movement of people and equipment to and from the work site may be expensive.
4. Utilization of equipment may be low because the equipment may be left at a location where it will be needed again in the next few days rather than moved to another location where it would be productive.

106.

**Sol.** **Steps of Forecasting**

To forecast demand, the following essential steps need to be taken:

1. **Determination of objectives of forecasting:** The objectives of forecasting should be clear. Without focused objective, forecasting is meaningless.
2. **Selection of the items to be forecast:** The forecast for one item cannot be used for the other item. Therefore, the item must be selected for which forecast is to be made.
3. **Determination of the time horizon of the forecast:** The nature of the product decides the time horizon of its demand forecast. A long-range forecast is more error-prone as compared to a short-range forecast. Therefore, the horizon or a range of forecasting is an important issue.

4. **Selection of the suitable forecasting model:** There are a number of forecasting models. The suitability of these models is to be checked for the forecast of a particular product. The choice should be of a forecasting model that would give a more accurate estimation of demand.
5. **Collection of the data:** Future is predicted on the basis of the past data. Therefore, the relevant past data should be collected from various sources such as annual reports, magazines, journals, etc.
6. **Validation of the forecasting model:** The selected forecasting model is to be validated using the collected data.
7. **Forecasting the demand:** After data collection and model validation, forecast is made for a specific time in the future.
8. **Implementation of the results:** Finally, the results are implemented to fulfil the objectives. Here, results mean the quantity/volume of product forecasting. The entire production systems are changed/adjusted to meet the expected demand in future.

107.

**Sol.** In this method, the forecasts of a panel of experts are elicited through a sequence of questionnaires. Each questionnaire builds on the previous questionnaire in a series of 'rounds.' The experts answer the questionnaires independent of each other. After each round, a facilitator provides an anonymous summary of the experts' forecasts from the previous round as well as the reasons they provided for their judgements. The experts are encouraged to revise their earlier answers in the light of the replies of other members of their panel. It is believed that the group will eventually reach a consensus. The process is stopped after a number of rounds or when a consensus is reached.

108.

**Sol.** In an organization, normally, four types of inventory are used as discussed below:

1. **Raw materials and parts:** These include all raw materials, components and assemblies used in the manufacture of a product.
2. **Consumables and spares:** These may include materials required for maintenance and day-to-day operations.
3. **Work-in-progress inventory:** These are items under various stages of production not yet converted as finished goods.
4. **Finished products:** These are finished goods not yet sold or put into use.

109.

**Sol. Objectives of Inventory Control**

The following are the objectives of inventory control:

1. To keep the investment in inventory to the minimum.
2. To minimize idle time by avoiding stock-outs and shortages.
3. To avoid carrying cost.
4. To improve customer satisfaction level with lesser inventory.
5. To avoid obsolescence of inventory.

110.

**Sol. Functions of Inventory**

The following are the functions of inventory:

1. **To meet anticipated demand:** The demand cannot be estimated with full accuracy. There is always chance of increasing or decreasing the demand due to various factors. To meet this uncertainty in demand variation or to meet the anticipated demand, inventory is required.
2. **To smooth production requirements:** There may be a sudden breakdown of the machine involved in production. In this situation, an inventory is required at each workstation to continue the production without any disruption.
3. **To decouple operations:** In case of product mix or multi-product production, we try to postpone the product differentiation towards the end of the production process, so that the demand of a customized product can be fulfilled very easily. Initially, a generic product is produced and at the end of production; these products are stored in generic form and finally customized as per demand. The point of customization or differentiation is known as decoupling point.
4. **To protect against stock-outs:** A safety or reserve stock is required to meet the shortages or delay in the replenishment of inventory. In case of shortages, production is disrupted or demand

of the customer remains unfulfilled which leads to poor customer satisfaction level. Thus, inventory is required to protect against stock-out.

5. **To help hedge against price increases:** The price of a product may increase in near future. In this case, inventory is required to help hedge against price increases.
6. **To take advantage of quantity discounts:** Inventory provides economies of scale. If we produce or purchase the items in bulk or batch, there may be provision of quantity discount.

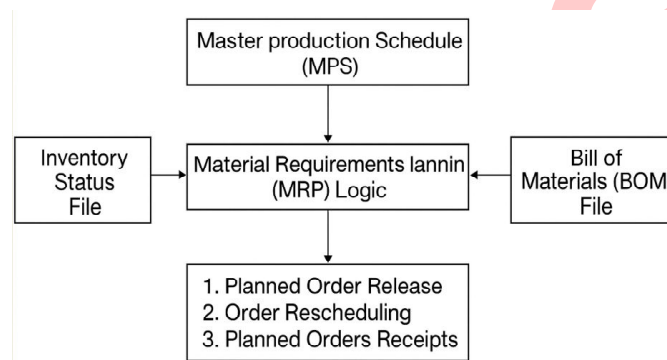
111.

**Sol. Materials Requirements Planning (MRP):**

- **Materials requirements planning** is a simple system of calculating arithmetically the requirements of the input materials at different points of time based on the actual production plan.
- It can be seen from the figure that an MRP system has three major input components:

The inputs to the MRP system are :

1. Master production schedule
2. Inventory status file
3. Bill of materials (BOM)



**Master Production Schedule (MPS):**

- MPS is designed to meet the market demand (both the firm orders and forecasted demand) in the future in the taken planning horizon.
- MPS mainly depicts the detailed delivery schedule of the end products. However, orders for replacement components can also be included in it to make it more comprehensive.

**Bill of Materials (BOM) File:**

- BOM represents the product structure.
- It encompasses information about all sub-components needed, their quantity, and their sequence of build-up in the end product.
- Information about the work centers performing build-up operations is also included in it.

**Inventory Status File:**

- The inventory status file keeps an up-to-date record of each item in the inventory.
- Information such as item identification number, quantity on hand, safety stock level, quantity already allocated, and the procurement lead time of each item is recorded in this file.

112.

**Sol.** The following are benefits of MRP:

1. Increased customer service and satisfaction.
2. Improved utilization of facilities and personnel.
3. Better inventory planning and scheduling.
4. Faster response to market changes and shifts.
5. Reduced inventory levels without reducing customer services.

The following are limitations of MRP:

1. Delays in scheduled receipts.
2. Changes in planned order sizes because of capacity constraints.
3. Changes in gross requirements which dictate changes in lot sizes at sub-component levels.

4. Unavailability of raw materials for one sub-component may negate the need for a fellow subcomponent as both must be ready for the parent production.
5. Utilization of the same parts at different levels, indicating the need to restructure the bill of materials.

113.

Sol. Difference MRP from MRP-II

| MRP                                                                                                                                                                                | MRP II                                                                                                                                                                  |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Stands for Material Requirements Planning.                                                                                                                                         | Stands for Manufacturing Resource Planning.                                                                                                                             |
| Developed in 1970s.                                                                                                                                                                | Developed in 1980s.                                                                                                                                                     |
| Widely used approach for production planning and scheduling in industry.                                                                                                           | Provides an information that is useful to all functional areas and encourages cross-functional interactions.                                                            |
| Aims at releasing and managing manufacturing orders and purchasing requisitions.                                                                                                   | Aims to control relevant material flows and production capacity while also taking into account the relationship between these material flows and the required capacity. |
| MRP is simply about ensuring the materials which are available to manufacture a specific part in a specific volume.                                                                | It takes care of all other aspects of a job including ordering, tracking inventory and ensuring capacity.                                                               |
| It takes inputs all in order to make sure you have the right amount of materials/labor/machinery on hand at any given time to satisfy the market or your company production goals. | MRP II uses additional data from accounting records and sales for further analysis and forecasting of manufacturing requirements.                                       |

114.

Sol. ERP stands for **Enterprise Resource Planning**. ERP systems integrate all business management functions including planning, inventory/materials management, engineering, order processing, manufacturing, accounting and finance, human resources etc. The biggest advantage of an ERP system based on its real-time capabilities and the ability to see what is going on with the organization as it happens. Installation of an ERP system has many advantages. The advantages may be both direct and indirect. The direct advantages include efficiency improvement, integration of information, faster response time to customer queries, etc. Example of indirect benefits include better corporate image, improved customer goodwill, customer satisfaction and so on. Some of the benefits are as follows :

- Integrating and sharing of information across different departments.
- Reducing redundant data entry and processes.
- Guarantee for the security of organization data.
- Better communication across various departments.
- Improving workflow and security.

115.

Sol. **Definition:** Material handling refers to the movement, protection, storage, and control of materials and products throughout the manufacturing, warehousing, distribution, consumption, and disposal processes. This encompasses a range of activities including lifting, moving, storing, and managing materials in various forms, from raw materials to finished goods.

**Relationship between material handling and plant layout:**

Plant layout is pre-production planning. Material handling and manufacturing process equipments are established as per requirement of plant layout. The material handling systems are to be integrated with the following material handling functions:

1. Transportation to the production facility
2. Receiving, storage and retrieval
3. Transportation to the work-centres/workstations
4. Transportation between operations and staging
5. Packaging and shipping

116.

**Sol. Functions of material handling system:**

The functions of material handling are as follows:

1. To plan the plant layout, building and production centre as per the suitability of a particular type of material handling equipments.
2. To minimize the movement of materials and material transportation time.
3. To optimize the speed of material handling equipments and devices.
4. To eliminate or minimize the backtracking.
5. To prevent the accident and facilitate the safe movement of materials.
6. To minimize the damage of materials during movement, loading and unloading.
7. To minimize the material handling costs.
8. To provide training to the persons operating the material handling equipments for their efficient handling and safe working.

117.

**Sol. Objectives of material handling systems:**

The objectives of materials handling are:

1. To increase the space utilization by keeping the materials in racks, one above the other. The material handling generally affects space requirements. Storing various types of materials like raw materials, parts, sub-assemblies, assemblies and finished parts is facilitated by material handling devices and methods, stored at proper space.
2. To improve the operating efficiency by reducing material handling. Increasing load per movement using the proper material handling devices improves productivity and saves cost of materials handling.
3. To ensure on-time delivery of the materials at different work centres/facilities. Materials, parts and finished products must be moved from the place of storage to their destination speedily and efficiently.
4. To reduce the production cost by increased capacity, improving working conditions, improving customer services, increased equipment and space utilization and reducing cost of materials handling.

118.

**Sol. Principles of material handling systems:**

Material handling is a technique, the efficiency of which is governed by the following principles:

1. The materials should be moved minimally as much as possible. The selection of production machinery and the type of the plant layout should be such that the long movement of material may be eliminated as far as possible.
2. The time of each move should be minimized. This can be attained through the shortest routes and use of mechanized or automated material handling equipment in place of manual labour.
3. The distance of each move should be minimized. This can be accomplished through the use of the shortest routes and elimination of backtracking.
4. The principle of unit load should be applied. According to this principle, the materials should be moved in lots rather than on an individual basis. The optimum number of pieces should be moved in one unit. The principal of unit load avails the economies in the form of reduced loading, labour cost, packing cost, elimination of damage and pilferage, savings in time and the effective utilization of material handling equipment.
5. The gravity feed should be used wherever possible as it is the cheapest source of motive power.
6. Re-handling and backtracking of the materials should be avoided. This can be attained through effective layout and efficient routing and scheduling.
7. The appropriate material handling equipment should be selected so that the safety, efficiency and flexibility can be maintained.



8. The design of the container, pallets, drums, etc. should entail economy in handling and reduce the material damages during the transit.
9. The material handling service must not interfere with the production flow.
10. The safety of the people must be taken care of and it should be the first preference.
11. The provision of the stand-by facilities should be made so that the sudden breakdown may not shut down the operations.
12. There should be periodical maintenance of material handling devices.
13. The material handling services should be evaluated periodically and necessary changes should be incorporated wherever it is possible.
14. The adverse effects on the environment should be minimized when selecting material handling equipment and procedures.
15. Simplify handling by eliminating, reducing or combining unnecessary movements and/or equipment.

119.

**Sol. Types of material handling equipments:**

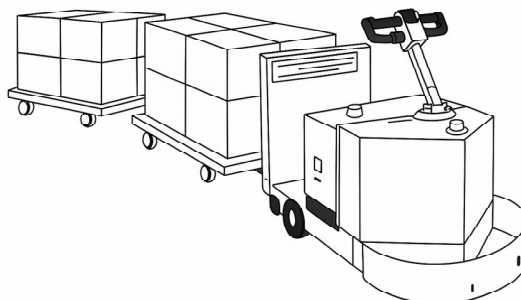
Material handling equipments can be classified into the following five major categories (Michael 2012):

1. **Transport equipments:** These are the equipments used to move material from one location to another (e.g. between workplaces, between a loading dock and a storage area, etc.). The major subcategories of transport equipments are conveyors, cranes and industrial trucks.
2. **Positioning equipments:** These equipments are used to handle material at a single location so that the material is in the correct position for subsequent handling, machining, transport or storage. Unlike transport equipments, positioning equipment is usually used for handling at a single workplace.
3. **Unit load formation equipments:** These equipments are used to restrict materials so that they maintain their integrity when handled a single load during transport and for storage. If materials are self-restraining (e.g. a single part or interlocking parts), then they can be formed into a unit load with no equipment.
4. **Storage equipments:** These equipments are used for holding or buffering materials over a period of time. Some storage equipments may include the transport of materials (e.g. the storage/retrieval machines of an automated storage/retrieval system).
5. **Identification and control equipments:** These equipments are used to collect and communicate the information that is used to coordinate the flow of materials within a facility and between a facility and its suppliers and customers. The identification of materials and associated control can be performed manually with no specialized equipment.

120.

**Sol. Automatic guided vehicle**

Automatic Guided Vehicles (AGVs) do not require any operator. They are good for high labour cost, hazardous, or environmentally sensitive, low-to-medium volume, medium-to-long distance random material flow operations (transport between work cells in a flexible manufacturing system environment). Two means of guidance used for AGV systems are: fixed path (wire, tape, paint for guidance) and free-ranging (software guided), but absolute position estimates (from lasers) are needed to correct dead-reckoning error.



121.

**Sol.** PPC is a crucial first step that businesses must take before starting the production process. It includes planning how the entire process will run from procuring raw materials and setting up machinery to scheduling tasks, choosing the right production method, and managing the workforce. The control part focuses on tracking the process and taking corrective actions when things go off track to ensure production goals are met efficiently and cost-effectively.

122.

**Sol.** **Work study:**

- The basic form of work system design is work study, which is used to achieve the desired function by using effective methods.
- The word "work-study" refers generally to the techniques, method studies, and work measurement used to examine human work in all of its circumstances.
- In order to make improvements, all the aspects that affect the effectiveness and economy of the working condition are methodically investigated.

**Purposes of Work Study**

The following are the purposes of conducting work study:

1. To standardize the method of doing a task.
2. To determine the standard time for doing a task, for use in the wage payment/determination.
3. To minimize the unit cost of production by selecting proper machine tools, optimum cutting parameters and proper process.
4. To minimize the materials movement and idle time of the workers and machines by proper layout of the plant.
5. To eliminate the unnecessary human motions in performing a task.
6. To utilize the facilities such as man, machine and materials most effectively.

123.

**Sol.** **\*\* What are the factors Influencing the production planning and control?**

**Factors affecting PPC (production planning and control)**

**There factors affecting PPC are as follows:**

1. **Use of computers:** Today, computers are used in most of the production activities, such as automation, computer-integrated manufacturing, computer-aided design and manufacturing, computer-aided process planning, computer-aided quality control, information and communication technology, radio frequency identification, automated storage and retrieval systems, etc.
2. **Seasonal variations in the demand:** Demand for certain products is affected by seasons, for instance, umbrellas, woolen clothes and raincoats. PPC must take such changes into consideration while planning and control activities of inputs and outputs.
3. **Test marketing:** With an aggressive marketing strategy, new products are to be test-marketed in order to know the trends. This is a short-cycle operation, intermittent in nature and often upsets regular production.
4. **After sales service:** This has become an important parameter for expansion of the target markets. In supporting the after sales services, many items are returned for repair. These are unscheduled work and also overload the production line.
5. **Losses due to unpredictable factors:** Losses may occur due to accidents, fire, earthquakes, tsunami and theft of production inputs, mainly materials and components. These are unpredictable. Shortage of input or disruption in the supply of the inputs due to such factors upsets the planned production schedule in time and quantity.
6. **Losses due to predictable factors:** There are losses of inputs, due to natural engineering phenomena like production losses and changes in consumption of materials and occurrence of defective.
7. **Production of order:** There are many occasions when in the last minute prioritization of existing orders takes place due to external pressure. These changes in priority are often decided by sufficiently high level of management.
8. **Design changes:** Design changes by R & D and the engineering department forces the PPC to change the input materials and process.



9. **Rejection and replacement:** There are many occasions when sub-assemblies or finished goods are rejected during production stage or final inspection. PPC must cater for contingency plans to take care of rework without affecting scheduled quality.

124.

Sol. **Motion Study or Method Study:**

It is a technique to record and time an activity/operation. It deals with

- Taking motion pictures of the operation of the study with a clock fixed by the side of the operation.
- Operating a motion picture camera or a video camera at a known constant speed.

**Steps to Conduct Method Study**

**Select:** In this step, a job or process is selected which is to be considered for method study.

**Record:** All the relevant facts/information about the process or the job is collected through data collection or direct observation.

**Examine:** All the data collected in second step are examined properly.

**Develop:** Some of the efficient and economical methods of doing that job or process are developed.

**Evaluate or Measure:** Results of different alternative methods are evaluated and the best one is selected.

**Define:** New method among the alternative is defined and presented.

**Install:** New method as standard practice is installed and persons in applying it are trained to use the new method.

**Maintain:** Control procedure is established and maintained.

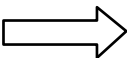
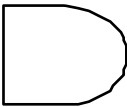
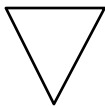
125.

Sol. **difference between method study and time study**

| Basis                            | Time Study                                                                                 | Motion Study/Method Study                                                                                             |
|----------------------------------|--------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------|
| <b>Meaning</b>                   | The study that determines the standard time taken to perform a job is known as Time Study. | The study of movements like lifting, putting objects, sitting and changing positions, etc., is known as Motion Study. |
| <b>Aim</b>                       | Its main aim is to determine the standard time taken to complete a task.                   | It aims to eliminate unnecessary movement while doing a work.                                                         |
| <b>Development of new method</b> | It does not develop new methods of doing work.                                             | It develops new methods of doing work by eliminating unnecessary movements.                                           |
| <b>Tools of Study</b>            | Measuring devices like stop watches are used in the study.                                 | Movie cameras connected with micro-chronometers are used in the study.                                                |

126.

**Sol.** Take these delays into consideration while developing the new method. Method study uses the symbols mentioned in table.

| S. No. | Activity                   | Symbol                                                                            | Remarks                                                                                                                                                                    |
|--------|----------------------------|-----------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1.     | Operation                  |  | Indicates the main process, method or operation.                                                                                                                           |
| 2.     | Inspection                 |  | Indicates an inspection for quality and/or check for quantity.                                                                                                             |
| 3.     | Transport                  |  | Indicates the movement of workers, materials or equipment from place to place.                                                                                             |
| 4.     | Temporary storage or delay |  | Indicates a delay in the sequence of events: for example, work waiting between consecutive operations, or any object laid aside temporarily without record until required. |
| 5.     | Permanent storage          |  | Indicates a controlled storage in which material is received into or issued from a store under some form of authorization; or an item is retained for reference purposes.  |

127.

**Sol.** **Taylor's Four Basic Principles of Scientific Management**

- Development of a true science of management so that the best method for performing each task could be determined.
- Scientific selection of workers so that each worker could be given responsibility for the task for which he/she was best suited.
- Putting a right worker in the right job is not enough; a system of financial incentives is also needed to motivate the workers.
- The functional division of labour between management and workers improves the productivity and intimates friendly cooperation between management and labour.

**Drawback of Taylor's Scientific Management**

The following are the drawbacks of Taylor's scientific management:

- Taylor was able to increase the productivity and pay in a number of instances, but workers and unions began to oppose his approach because they feared that working harder or faster would exhaust whatever work was available causing layoffs.
- Taylor's critics objected to the speed-up condition that placed undue pressure on employees to perform faster and faster.
- The emphasis on productivity and by extension on profitability led some managers to exploit both the workers and customers.
- Owing to the above-listed adverse effects, more workers joined unions thus reinforcing a pattern of suspicion and mistrust that clouded labour relations for decades.

128.

**Sol.** **Henri Fayol's 14 Principles of Management**

Henri Fayol, a French mining engineer, developed 14 principles of management based on his management experiences. These principles are described as follows.



1. Division of work: Division of work and specialization improves the productivity with the same effort.
2. Authority and responsibility: Authority is the right to give orders and the power to exact obedience. Authority creates responsibility for getting the work completed.
3. Discipline: Obedience, respect and proper behaviour within an organization are absolutely essential.
4. Unity of command: An employee should receive orders from only one superior.
5. Unity of direction: Organizational activities must have one central authority and one plan of action.
6. Subordination of individual interest to general interest: The interests of one employee or group of employees are subordinate to the interests and goals of the organization.
7. Remuneration of personnel: Salaries - the price of services rendered by employees should be fair and should provide satisfaction to both the employee and the employer.
8. Centralization: The objective of centralization is the best utilization of personnel. The degree of centralization varies according to the dynamics of each organization.
9. Scalar chain: A chain of authority, that is, scalar chain, exists from the highest organizational authority to the lowest ranks.
10. Order: An organizational order for materials and personnel is essential. Right materials and right employees are necessary for each organizational function and activity.
11. Equity: In organizations, equity is a combination of kindness and justice. Both equity and equality of treatment should be considered when dealing with employees.
12. Stability of tenure of personnel: To attain the maximum productivity of personnel, a stable workforce is needed.
13. Initiative: Thinking out a plan and ensuring its success is an extremely strong motivator. Zeal, energy and initiative are desired at all levels of the organizational ladder.
14. Esprit de corps: Teamwork is fundamentally important for an organization. Work teams and extensive face-to-face verbal communication encourage teamwork.

129.

Sol.

$$\text{Net rate of return} = (12 - 3)\% = 9\%$$

$$\text{Present worth of machine} = 3000 \left[ \frac{(1 + 0.09)^{18} - 1}{0.09(1 + 0.09)^{18}} \right] = \text{Rs. } 262668.75$$

At the break even point,

$$\text{F.C.} + (\text{VC})N = (\text{SP})N$$

$$\therefore N = \frac{\text{Fixed cost}}{-\text{VC} + \text{SP}} = \frac{262668.75}{9 - 6} = 87556.25$$

$$\text{Break even quantity} = 87556$$

130.

Sol.

ABC analysis is an analysis of a range of objects, such as finished products, items lying in inventory or customers into three categories. It is a system of categorization, with similarities to Pareto analysis, and the method usually categorizes inventory into three classes with each class having a different management control. ABC concept is popularly known as "80/20" rule and is applied to reviewing inventory, a company should rate items from A to C on the following rules:

A-Items: 10-20% of the items account for 70-80% of the value consumption.

B-Items: 15-25% of the items account for 10-20% of the value consumption.

C-Items: 65-75% of the items account for 5-10% of the value consumption.

'A' class items are closely monitored because of the value involved is 70-80%.

131.

Sol.

$$D = 200 \text{ units/month}$$

$$C_0 = \text{Rs. } 20/\text{order}$$

Assuming carrying cost is given per month, so

$$C = 25\% \text{ of } C_0$$



$$\text{EOQ at unit price } C = \text{Rs. } 10, \quad \text{EOQ}_1 = \sqrt{\frac{2DC_0}{C_c}} = \sqrt{\frac{2 \times 200 \times 20}{2.5}} = 56.56 \text{ Not feasible EOQ}$$

$$\text{EOQ at unit price } C = \text{Rs. } 9, \quad \text{EOQ}_2 = \sqrt{\frac{2DC_0}{C_c}} = \sqrt{\frac{2 \times 200 \times 20}{2.25}} = 59.62$$

At

$$\text{EOQ}_2 = 59.62 \text{ Feasible EOQ}$$

$$(\text{Total cost})_{\text{EOQ}} = \text{Ordering cost} + \text{Carrying cost} + \text{Item cost}$$

$$= \frac{200}{59.62} \times 20 + 2.25 \times \frac{59.62}{2} + 200 \times 9 = 67.09 + 67.07 + 1800$$

$$= \text{Rs. } 1934.16/\text{month}$$

$$\text{Total cost at } Q = 100 \text{ units}$$

$$\therefore \text{Total cost} = \frac{200}{100} \times 20 + 2 \times \frac{100}{2} + 200 \times 9 = 40 + 100 + 1800 = \text{Rs. } 1740 / \text{month}$$

Optimal order quantity,

$$Q = 100 \text{ units}$$

132.

**Sol. (i) Critical path:** The path forming an unbroken chain of critical activities from the start event to the end event is called the critical path. It is the path of longest route. In the execution of the project, it is the critical path which needs optimum care. Any delay in any activity on this path will upset the whole project and will delay its completion. That is why the name critical path is assigned to this path.

**(ii) Project graph:** The graph that depicts the combination of interrelated activities which must be performed in a certain order for its completion is called the project graph.

This project graph sensibly takes into account (or projects) dummy activities, partial dependency of one activity over the other. In this graph, looping problem can be avoided by numbering them in a logical sequence. It gives different relations between activities, which help us to know which activity should be completed first.

**(iii) Early start time:** This is the earliest occurrence time of the event from which the activity starts.

**Early finish time:** This is the earliest start time of the activity plus the duration of activity.

Otherwise, this is the earliest time that an activity can finish from the beginning of the project.

These times are helpful in finding the critical path apart from latest start and latest finish times.

133.

**Sol.** Customers (m/c, vehicles, students, people etc) arrive at a constant or variable rate for services at service facilities. If the service facility is free, they are served immediately. If the service facility is busy providing services to other customers, the newly arrived customers have to wait. Thus if they must wait for services, they either begin a queue or join on existing queue, and remain in the queue until they are served.

#### Queuing models with Poisson input - Exponential service

**Model 1:** Infinite queue, Infinite source, Single server.

**Model 2:** Infinite queue, Infinite source, Multiple server.

**Model 3:** Finite queue, Infinite source, Single server.

**Model 4:** Finite queue, Infinite source, Multiple server.

#### Application of queuing model:

- Retail shops
- Airports check-in
- Automobile service centers
- Doctor's office
- Traffic congestion
- Railway wagon yard

134.

**Sol.** Various steps in value analysis are:

1. **Orientation:** This phase involves identification of the problem very clearly, selection of projects, formation of teams, laying down objective and target and in-depth training of all the team members.

2. **Information gathering:** After completion of orientation, all the information like drawing and technical specification manufacturing processes, detailed cost breakup is gathered.
3. **Functional analysis:** This step involves analysis and identification of functions.
4. **Creation of alternative:** This is the essence of value engineering. All the possible alternatives are generated. This can be achieved by application of brain storming and other creativity technique in order to generate a large number of ideas.
5. **Evaluation:** In this phase the possible alternatives developed are analysed. The cost of each idea is estimated. Critical evaluation of all point are carried out.
6. **Investigation/development:** The shortlisted ideas are investigated and in depth analysis is done to arrive at optimum and practical solution.
7. **Implementation:** as a result of all these steps, a definite specific and tangible solution acceptable to all is reached and implemented.
8. **Follow up:** this is the final step which compares the result with original expectation and suggest corrective actions.

135.

Sol.

- (i) The value engineering job plan consists of the following phases
- |                          |                         |
|--------------------------|-------------------------|
| (a) Orientation phase    | (b) Information phase   |
| (c) Functional phase     | (d) Creation phase      |
| (e) Evaluation phase     | (f) Investigation phase |
| (g) Recommendation phase |                         |
- (ii) (a) Several NC machines are directly controlled by a computer eliminating substantial hardwares.  
 (b) The DNC computer downloads the program directly to the CNC computer memory.  
 (c) The DNC computer can program simultaneously many machines.  
 (d) The computer can be remotely located, even a thousand miles away.  
 (e) Maintenance is easy.

136.

Sol.

'Labour legislation' is a body of law formed for the working class of people to provide them with legal rights, and also restrict them with rules and regulations. It defines the rights and obligations of the working class. Labour law covers several areas-

- **Certification of Labour Unions** - The Labour Union is issued with a formal document which ensures them the right to represent on behalf of all the labourers. This Union acts as an exclusive bargaining agent.
- **Collective Bargaining** - The workers through their unions put demands before their employers, like the terms of their employment, payment, leave, health and safety policies and the number of working hours.

137.

Sol.

#### **Principles of labour legislation**

There are various principles of labour legislation-

- **Principle of Social Justice** - It ensures social equality for people and ensures that opportunities aren't denied to them on the basis of religion, caste or any other prejudicial grounds. No matter whichever place they come from they must be provided with equal opportunities to work. Their social status should not be considered a ground for anything and they should be treated in a well-mannered way. The profits earned by a company must be distributed on fair grounds between the workers and the owner.
- **Social Equity** - It mentions that the maintenance of labour is based on social equity of labour. As the time and circumstances keep changing it demands new laws and rules to suit workers' needs accordingly. This intervention of the government in bringing new Acts and amendments according to the situation prevailing is based upon social equity. 'Equity' means to be fair and impartial. Social equity means to form equal working standards for the people with the help of provisions and obligations to do so. Laws should be flexible enough to meet the demands of the industrial society.

138.

**Sol. Objectives of labour legislation**

- Establishment of all kinds of justice for the working people - social, economic, and political.
- The availability of equal opportunities to all workers, irrespective of caste, creed, religion and beliefs for their overall personality development.
- Protection of weaker sections of workers who are not financially well off to protect themselves.
- Maintenance of industrial peace.
- Protection and improvement of living standards of the labourers.
- Protection of workers from all sorts of exploitation - mentally or physically and creating a better working environment.
- Grant rights to workmen to unite and form their unions so that they could bargain collectively with their owners for the betterment of their livelihood.
- Keep checks on the government about their active participation in the working areas for social well-being.
- Ensures human rights and human dignity.

139.

**Sol. History and development of labour legislation**

The roots of labour legislation lie in the relentless struggle faced by the workers at their master's work. There was inequality between two classes of people. The contract between labour and capital could never be struck on equitable terms. Such practices required a change, and this need became the basis for the formation of labour laws.

140.

**Sol.** Effective Emission Control is often overlooked when looking at opportunities to move towards smart manufacturing practices. Dust and Fume Emissions are however often reasons to lose a license to operate or accidents related to **Operator Health & Safety** or **Explosion Safety**. Emission Control is often just a 'utility' but when addressed properly, it can contribute tremendously to your operations. By implementing Industry 4.0 innovations related to emission control, there is one less thing to worry about.

**Risks of adopting industry 4.0 solutions**

While the benefits of adopting Industry 4.0 solutions in the manufacturing industry are vast, there are also risks that need to be considered. The biggest concerns can be summarized as:

- **Lack of available skills.** Nobody has done it before and partners do not have a proven track record to assist implementation. Also, there is still a general reluctance from stakeholders, senior management and investors to adopt new technologies.
- **Uncertainty about Cybersecurity.** As human fault is made easily. Interconnectedness may lead to breaches and hacks. A solution may be to use a private cloud. Another solution is to make 'one-way communication' so information can be read out from a distance, but operations cannot be controlled from afar.
- **Uncertainty about benefits.** Will it be worth it? What's the ROI? Large investments need to be made and other operational improvements might cost less.

141.

**Sol.** Four commonly used methods of reading a stop watch are as follows: (1) Continuous Timing (2) Fly-back Timing (3) Accumulative Timing (4) Differential Timing Method.

**(2) Fly-back Timing:**

In this timing method, the reading of fly-back type stop watch is taken at the end of each element and then, the stem is depressed simultaneously. Due to this depression the hands of the watch go back to zero and start off again. Thus, no subtraction is required in this method as the watch readings at the end of each element are the actual element times. This method has got only advantage of less calculation.

**At the same time, it suffers from a lot of disadvantages such as:**

- (a) Once an element is missed, there is no means by which it can be taken into account afterwards.
- (b) It is difficult to train the analysts in this method.
- (c) This method requires a lot of skill as two things are to be done by analyst at the same time i.e., recording the time and pressing the stem knob.



## PART - C

## 20 Marks Questions

142.

Line balancing is the distribution of load on different workstations to minimize the idle time. All the different activities of a task or an assembly has different processing times that lead to idle time on the workstations having shorter processing time. Line balancing is concerned with the way assigning of activities so that the idle time can be minimized.

The work to be performed at a workstation is equal to the sum of the tasks assigned to that workstation. The assembly line balancing problem is related to assigning all the tasks to be performed in a series of workstations so that each workstation has no more than can be done in the workstation cycle time, and so that the idle time across all workstations is minimized. The problem is complicated due to precedence relationship among the work elements or tasks. There are certain rules of line balancing as given below:

1. Identify the cycle time and determine the minimum number of workstations using the following formulas:

$$\text{Cycle time, } C = \frac{\text{Production time per day}}{\text{Total number of units required per day}}$$

$$\text{Theoretical number of workstations, } N_1 = \frac{\text{Sum of task time (T)}}{\text{Cycle time (C)}}$$

2. Tasks are assigned to work stations moving left to right through the precedence diagram.
3. Before each assignment, use the following criteria to determine which tasks are eligible to be assigned to a workstation
  - (a) All proceeding tasks should be arranged in the sequence.
  - (b) The task time does not exceed the time remaining at the workstation, if no task is eligible, move to the next workstation.
4. After each task assignment, determine the time remaining at the current workstation by subtracting the sum of task times already assigned to it from the cycle time.
5. Break ties, if any, using the following rules:
  - (a) Assign the task with the longest task time.
  - (b) Assign the task with the greatest number of followers.
  - (c) If there is still a tie, choose one task arbitrarily.
6. Continue until all tasks have been assigned to work stations.
7. Compute appropriate measures (per cent idle time and efficiency) for the set of assignments.

$$\text{Efficiency} = \frac{\text{Sum of task time (T)}}{\text{Actual number of work stations (N}_a\text{)} \times \text{Cycle time (C)}}$$

8. If efficiency is unsatisfactory, rebalance using a different decision rule.

143.

Sol.

**Classifications of Inventory:**

The methods used to analyse the items in inventory are discussed in the following subsections.

**(a) Always Better Control (ABC) Analysis:**

As is evident from the above heading, 'ABC' connotes 'Always Better Control.' The basis of analysing the annual consumption cost of the inventory items is the principle 'Vital Few – Trivial Many,' and the criterion used here is the money spent, not the quantity consumed. Figure 6.1 shows the value and corresponding units in inventory. A-class items are very important and have value up to 70 per cent, but their inventory used is up to 10 per cent. B-class items are of moderate importance and have a value up to 20 per cent and also their inventory used is up to 20 per cent. C-class items are of lower importance and have a value up to 10 per cent, but inventory up to 70 per cent.

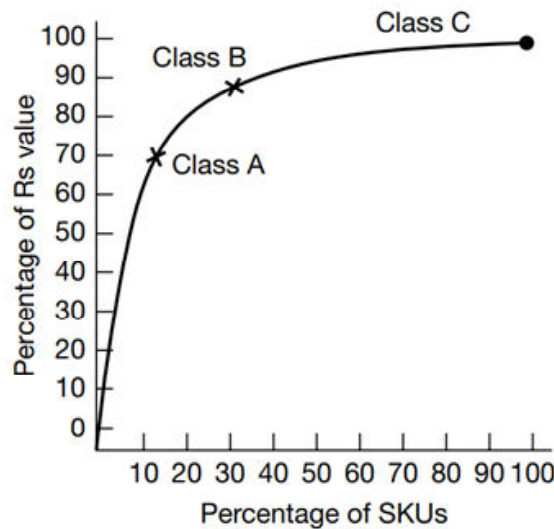


Fig.- ABC analysis

**(b) Vital, Essential and Desirable (VED) Analysis:**

The inventory items, when subjected to analysis based on their criticality, can be classified into vital, essential and desirable (VED) items. This analysis is termed as VED analysis.

1. Vital: Items without which production or a system comes to a standstill. The non-availability of these items cannot be tolerated.
2. Essential: Items whose non-availability can be tolerated for 2-3 days because similar or alternative items are available.
3. Desirable: Items whose non-availability can be tolerated for a long period.

Although the proportion of vital, essential and desirable items varies from company to company depending on the type and quantity of workload, on an average vital items are 10 per cent, essential items are 40 per cent and desirable items are 50 per cent of the total inventory available.

**(c) Fast, Slow-Moving and Non-moving (FSN) Analysis:**

Fast, slow-moving and non-moving (FSN) analysis is based on the rate of consumption of inventory items. The items can be classified as fast-moving, slow-moving and non-moving items. An understanding of the movement of items helps in keeping proper levels of their inventory by deciding a rational policy or reordering. Here, rational policy is concerned with decisions about reorder point and order size as per consumption of the items. This method is based on the fact that some stock items have a much higher annual usage than others.

**(d) Scarce, Difficult, or Easy (SDE) Analysis:**

The classification of inventory items is based on their availability that could be scarce, difficult or easy (SDE). The importance and storage of an item are decided on the basis of difficulty or ease of its availability.

1. S refers to scarce items, especially imported ones and those which are very much in short supply.
2. D refers to difficult items which are procurable in the market, but not easily available. For example, items which have to come from far off cities or there is not much competition for them in the market or their good quality supplies are difficult to get or procure.
3. E refers to easy items. These are mostly local items which are easily available.

144.

**Sol. Factors Influencing the Method Study**

In method study, an industrial engineer has to consider the following factors:

1. Motion economy factors.
2. Economic factors.
3. Technical factors.

4. Human factors.
5. Operational complexity.
6. Delays.

**Motion economy factors:** When a job is considered for method study, one has to think of whether there is a possibility of reducing the unnecessary motions. The jobs that are performed regularly, the micro-motion studies may expose such unnecessary motions. By economizing these motions, we can save human energy and utilize it for higher productivity.

**Economic factors:** Before conducting the study, one has to think is it worth to conduct motion or micro-motion study? If a work selected for investigation results in a very small economy, it is suggested that the study should not be conducted. One may have to consider the economy in removing the bottlenecks in movements and process such as movement of materials in one operation to the other, layout of machines, operational sequences, etc.

**Technical factors:** When a new method is developed and implemented, it is required to check availability of adequate technical knowledge and resources required in the method. This is a constraint for development of new methods. In most of the cases, technical factors and economic factors are interlinked.

**Human factors:** This factor is difficult to evaluate because it is associated with physiological, psychological and anatomical features of human beings. But these difficulties can be overcome to some extent through scientific methods such as ergonomics. If workers and their representatives are allowed to participate in problem formulation and implementation, the problem can be eliminated. The full and active participation from the workers' side and a due consideration to their views from the management side would reduce the difficulties and gives an impression among the workers that the new methods are for their betterment.

**Operational complexity:** When a method study is taken up for a job, most often the managers forget to take such operational complexity/flexibility into consideration. It is the industrial engineer's responsibility to bring out detailed description about the operational flexibility or complexity, so that the critical examination can be facilitated to check under these constraints.

**Delays:** There are three types of delays unavoidable delay, avoidable delay and planned rest pauses. In unavoidable delay, operators cannot avoid the delay, for example, operator inevitably waits for the material to come or for his turn to do the job; heat-treated products have to be cooled before an operation on a certain machine; welded joints are allowed to cool before taking for operation, etc. The avoidable delays can be avoided by proper planning. For example, a machinist need not have to wait if cleaning is done prior to his arrival. The third type of delay is planned rest pauses. These are also inevitable but somewhat flexible to change their schedules or duration in accordance with ergonomics studies. The industrial engineers who conduct method study must take these delays into consideration while developing the new method.

145.

**Sol.** Management is a very broad term and defined in a number of ways. But, all the definitions focus on the effective and efficient utilization of resources to achieve the goal. Management is the process of using organizational resources to achieve the organization's goals by planning, organizing, leading and controlling. In a simple way, management can be defined as an art and science used to get the work done. Some more definitions of management are given below:

Management is the coordination of all resources through the process of planning, organizing, directing and controlling in order to attain stated objectives.

-Henry L. Sisk

Management is the art and science of organizing and directing human efforts applied to control the forces and utilize the materials of nature for the benefit of man.

-ASME

Management is the art of knowing what you want to do and then seeing that it is done in the best and cheapest way.

-F. W. Taylor

### Nature of Management

Some important characteristics of management are described below.

- (a) **Management is an art as well as science:** Management uses theoretical knowledge to manage the activities or task, which is known as art, and at the same time, management uses a number of mathematical/scientific tools and techniques to improve the efficiency of a system, which is a part of science. Thus, we can say that management has two faces of a coin: on one side, it is art and on the other it is science. Management has got scientific principles which constitute the elements of science and skill and talent which are the attributes of art.
- (b) **Management is goal-oriented:** The basic goal of management is to improve the efficiency and economy in the utilization of all the available resources. The effectiveness of management is measured by the extent to which the established organizational or other goals are achieved.
- (c) **Management is a profession:** Management is used as profession and profession requires specialized knowledge and often, long intensive academic preparation. The essential features of a profession are: a well-defined body of knowledge, restricted entry, service motive, code of conduct, representative professional association.
- (d) **Management is universal:** Management is an essential part of all the activities irrespective of nature. All the different types of organizations or businesses require management regardless of size. The principles of management are applicable in all areas of organized activities. Managers at all levels and in all organizations perform the same basic functions.
- (e) **Management is an integrative force:** The importance of management lies in the coordination; it facilitates among the people in an organization. Management relates the individual goals to organizational goals. It integrates all the different resources.
- (f) **Management is multidisciplinary:** Management consists of knowledge derived from several disciplines such as engineering, sociology, psychology, economics and anthropology. Thus, it is multidisciplinary in nature.
- (g) **Management is a social process:** Human relation is the most important part of management. According to Appley, 'Management is the development of people not the direction of things. It is the pervasiveness of human element which gives management its special character as a social process.'
- (h) **Management is a continuous process:** The cycle of management continues to operate until its objective or goal is achieved.
- (i) **Management is intangible:** Management is an intangible activity. It cannot be seen directly, but its presence can be felt everywhere in the form of results. However, the managers who perform the functions of management are very much tangible and visible.

146.

**Sol.** The analysis which provides a relationship between revenues and costs with respect to volume (quantity) of sales and represents the level of sales at which costs and revenues are in equilibrium, is called break-even analysis. It is useful to the manager in the following ways:

What volume of sales will be necessary to cover.

- (i) A reasonable return on capital employed.
- (ii) Preference and ordinary dividends.
- (iii) Reserves.
- Computing costs and revenues for all possible volumes of output to fix budgeted sales.
- To find the price of an article to give the desired profit.
- To determine variable cost per unit
- To compare a number of business enterprises by arranging their earnings in order of magnitude.

Given,

$$\text{Selling price/unit} = \text{Rs. } 100 = \text{S.P.}$$

$$\text{Variable cost/unit} = \text{Rs. } 60 = \text{V.C.}$$

$$\text{Fixed costs} = \text{Rs. } 10,00,000 = \text{F.C.}$$

$$\text{Break even quantity, } Q_b = \frac{\text{F.C.}}{\text{S.P.} - \text{V.C.}} = \frac{10,00,000}{100 - 60} = 25000 \text{ units}$$

Given that variable cost have increased by 10%

$$\therefore \text{V.C.'} = 60 + \frac{10}{100} \times 60 = \text{Rs. } 66$$

Fixed cost have increased by 5%

$$\therefore F.C.' = 1000000 \times \frac{5}{100} + 1000000 = \text{Rs. } 1050000$$

But break even quantity is to remain constant

$$\therefore Q_B = 25000 = \frac{F.C.}{S.P.' - V.C.'} = \frac{1050000}{S.P.' - V.C.'} \Rightarrow S.P.' = \text{Rs. } 108 \quad (\text{new sales price})$$

$$\therefore \text{Percentage increase in sales price} = \frac{108 - 100}{100} = 0.08 = 8\%$$

147.

**Sol.** Maintaining an inventory is necessary because of the following reasons:

- It helps in smooth and efficient running of an enterprise. It decouples the production from customers and vendors and simplifies the otherwise complex organisation for manufacture and reduces the co-ordination effort.
- It provides services to the customer at a short notice. Timely deliveries can fetch more goodwill and orders.
- In the absence of inventory, the enterprise may have to pay high prices because of piecemeal purchasing. Maintaining of inventory may earn price discount because of bulk purchasing. It also takes advantage of favourable market.
- It reduces product costs since there is an added advantage of batching and long, uninterrupted production runs.
- It acts as a buffer stock when raw materials are received late and shop rejections are too many.
- Process and movement inventories (also called pipeline stocks) are quite necessary in big enterprises where significant amount of time is required to transship items from one location to another.
- Bulk purchases will entail less orders and, therefore, less clerical costs. This applies to goods produced within the organisation as well. Less orders, as a result of larger lots, will entail lesser machine setups and other associated costs.
- An organisation may have to deal with several customers and vendors who are not necessarily near it. Inventories, therefore, have to be built to meet the demand at least during the transit time.
- It helps in maintaining economy by absorbing some of the fluctuations when the demand for an item fluctuates or is seasonal.

Each order has associated with it the ordering cost or acquisition cost. To keep it low, the number of orders should be as few as possible. i.e., the order size should be large. But large order size would imply high inventory carrying cost. Hence the need of optimisation of order quantity is arisen.

Given, Demand,  $D = 10,000$  pieces/year. Order cost,  $C_0 = \text{Rs. } 240/\text{order}$

Inventory carrying cost or holding cost = 1% of Rs. 50/month

$$C_h = \frac{1}{100} \times 50 \times 12 / \text{year} = \text{Rs. } 6 / \text{year} / \text{item}$$

$$EOQ = \sqrt{\frac{2DC_0}{C_h}} = \sqrt{\frac{2 \times 240 \times 10000}{6}} = 894.42 \text{ components} / \text{procurement}$$

148.

**Sol.** Activity Expected time  $t_e = \frac{(t_0 + 4t_m + t_p)}{6}$

where,  $t_0$  = optimistic time,  $t_m$  = most likely time  
and  $t_p$  = pessimistic time

$$A = \frac{(1 + 4 \times 3 + 5)}{6} = \frac{18}{6} = 3$$

$$B = \frac{(2 + 4 \times 3 + 4)}{6} = \frac{18}{6} = 3$$

$$C = \frac{(3 + 4 \times 4 + 5)}{6} = \frac{24}{6} = 4$$

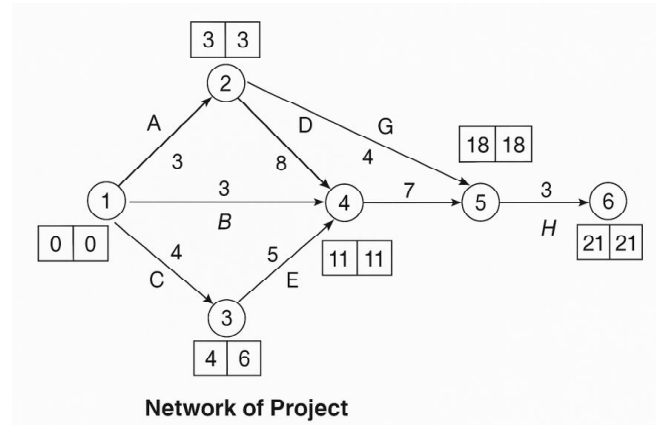
$$D = \frac{(2 + 4 \times 9 + 10)}{6} = \frac{48}{6} = 8$$

$$E = \frac{(4 + 4 \times 5 + 6)}{6} = \frac{30}{6} = 5$$

$$F = \frac{(5 + 4 \times 6 + 13)}{6} = \frac{42}{6} = 7$$

$$G = \frac{(2 + 4 \times 4 + 6)}{6} = \frac{24}{6} = 4$$

$$H = \frac{(0 + 4 \times 3 + 6)}{6} = \frac{18}{6} = 3$$



| Event      | 1 | 2 | 3 | 4 | 5 | 6 |
|------------|---|---|---|---|---|---|
| Slack time | 0 | 0 | 2 | 0 | 0 | 0 |

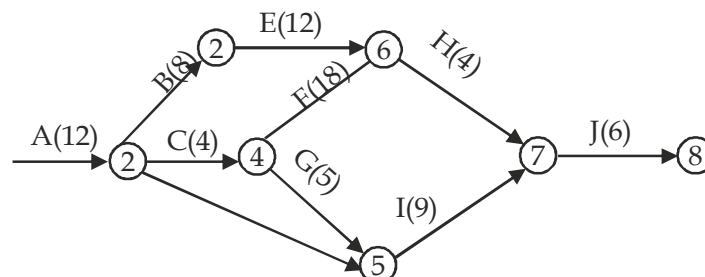
Critical path A → D → F → H

Critical time = 21 units.

149.

Sol.

| PERT                                                                             | CPM                                                                                               |
|----------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------|
| 1. Programme (project) evaluation and review technique.                          | 1. Critical path method.                                                                          |
| 2. It is event oriented.                                                         | 2. It is activity oriented.                                                                       |
| 3. It is associated with probabilistic activities.                               | 3. It is associated with deterministic activities.                                                |
| 4. It is based upon three time estimate to complete an activity.                 | 4. It is based upon single time estimate to complete an activity.                                 |
| 5. It is used where time required to complete various activities is not certain. | 5. It is used for repetitive job where one has prior experience of handling similar project.      |
| 6. It usually does not consider cost analysis. (Crashing is not used)            | 6. It gives importance to cost analysis and crashing is done to minimize the cost of CPM project. |
| 7. It is mainly used for research and development project.                       | 7. It is mainly used for construction project.                                                    |



| Path              | Duration (days)          |
|-------------------|--------------------------|
| A → B → E → H → J | 12 + 8 + 12 + 4 + 6 = 42 |
| A → C → F → H → J | 12 + 4 + 18 + 4 + 6 = 44 |
| A → C → G → I → J | 12 + 4 + 5 + 9 + 6 = 36  |
| A → D → I → J     | 12 + 3 + 9 + 6 = 30      |

Critical path : A → C → F → H → J

Project Duration : 44 days

150.

Sol.

- (i)
- **Earliest start time (EST):** It is the earliest time at which an activity can start.  $EST = E$
  - **Latest finish time (LFT):** It is the latest time by which the activity must be completed so that the scheduled date for the completion of the project may not be delayed.  
 $LFT = L$
  - **Total float (TF) (or) Total slack (TS):** Total float is the extra time which is available with any parallel activity without affecting the project completion time. The calculation of slacks or floats is used to determine the critical activities in a project network.  

$$\text{Total float} = LFT - EST$$

$$\text{Total float} = L_j - (E_i + t_{Eij})$$
  - **Free float:** It is the amount of time by which an activity can be delayed without delaying the earliest starting time of any successor activity.  

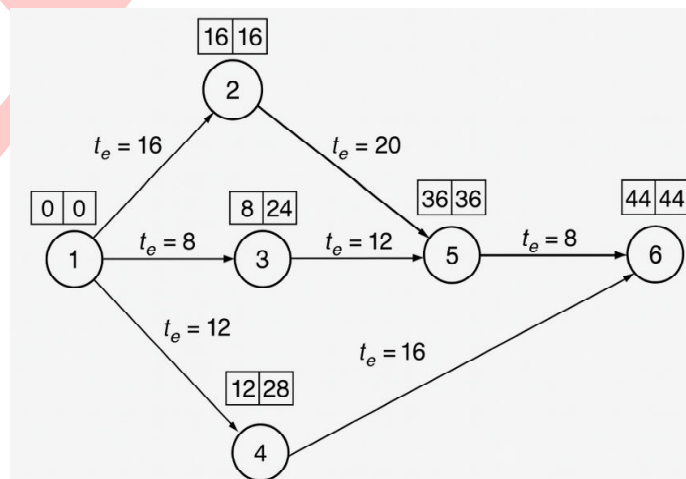
$$\text{Free float} = \text{Total float} - \text{Head event slack}$$

$$= E_j - (E_i + t_{Eij})$$
  - **Independent float (IF):** It is the amount of time which can be used without affecting either the head or tail event.  

$$\text{Independent float} = \text{Free float} - \text{Tail event slack}$$

$$= E_j - (L_i + t_{Eij})$$

where,  $E_i$  = Earliest start time,  $E_j$  = Earliest finish time,  $L_j$  = Latest finish time and  $L_i$  Latest start time.
  - **Critical activities and critical path:** The activities for which total float (TF) is zero are "Critical activities", any delay on the critical activities will affect the project completion. Combination of critical activities is called critical path and it tells us that 'in how much time project can be completed'. It is the longest path.  
 The critical path is represented by double thick arrow line to distinguish it clearly.



Different paths are:

$$1 - 2 - 5 - 6 = 44 \text{ days (maximum time)}$$

$$1 - 3 - 5 - 6 = 28 \text{ days}$$

$$1 - 4 - 6 = 28 \text{ days}$$

∴ **Critical path 1 - 2 - 5 - 6**

151.

**Sol.** (i) The various assumptions that are to be considered while solving a linear programming problem are:

1. There is a well defined objective function such as maximizing profit or minimizing cost.
  2. There are a number of restrictions or constraints (on the amount and extent of available resources for satisfying the objective function) which can be expressed in quantitative terms. These may refer to man-hours, machine hours, raw material, storage space, capital etc.
  3. The parameters are subject to variation in magnitude.
  4. The relationship expressed by constraints and the objective function is linear.
  5. The objective function is to be optimised with respect to the decision variables involved in the phenomenon. The decision variables are non-negative and represent real life situation.
- (ii) The given problem can be formulated with the help of following transportation matrix.

|   | X   | Y  |     |
|---|-----|----|-----|
| A | 30  | 20 | 50  |
| B | 50  | 80 | 110 |
|   | 100 | 60 | 160 |
|   |     |    | 160 |

**Objective function:**

To minimize,  $Z = 30X_A + 20Y_A + 50X_B + 80Y_B$

Since, the demand and supply are equal, the given problem is balanced, Applying Vogel's approximation method,

|   | X     | Y       |               |
|---|-------|---------|---------------|
| A | 30    | 20      | 50/0 10       |
| B | 50    | 80      | 110/10/0 (30) |
|   | 100/0 | 60/10/0 |               |
|   | 20    | (60)    |               |

$$Z = 50 \times 20 + 50 \times 100 + 80 \times 10 = \text{Rs. } 6800$$

Applying u-v method to check optimality:

Cost matrix for allocated cells:



|    |    |    |
|----|----|----|
|    | 0  | 30 |
|    |    | 20 |
| 50 | 50 | 80 |

$U_i + V_j$  matrix for unallocated cells:

|     |     |    |
|-----|-----|----|
|     | 0   | 30 |
| -10 | -10 |    |
| 50  |     |    |

Subtracting  $U_i + V_j$  cell values from original matrix.

|    |  |
|----|--|
| 20 |  |
|    |  |

Since no cell value is negative, the solution is optimum. Hence to minimise the transportation cost, 20 units must be supplied from Y to A, 80 from Y to B and 50 from X to B.

152.

Sol. Let

$j$  = Index for operator varying from 1, 2, ..., n

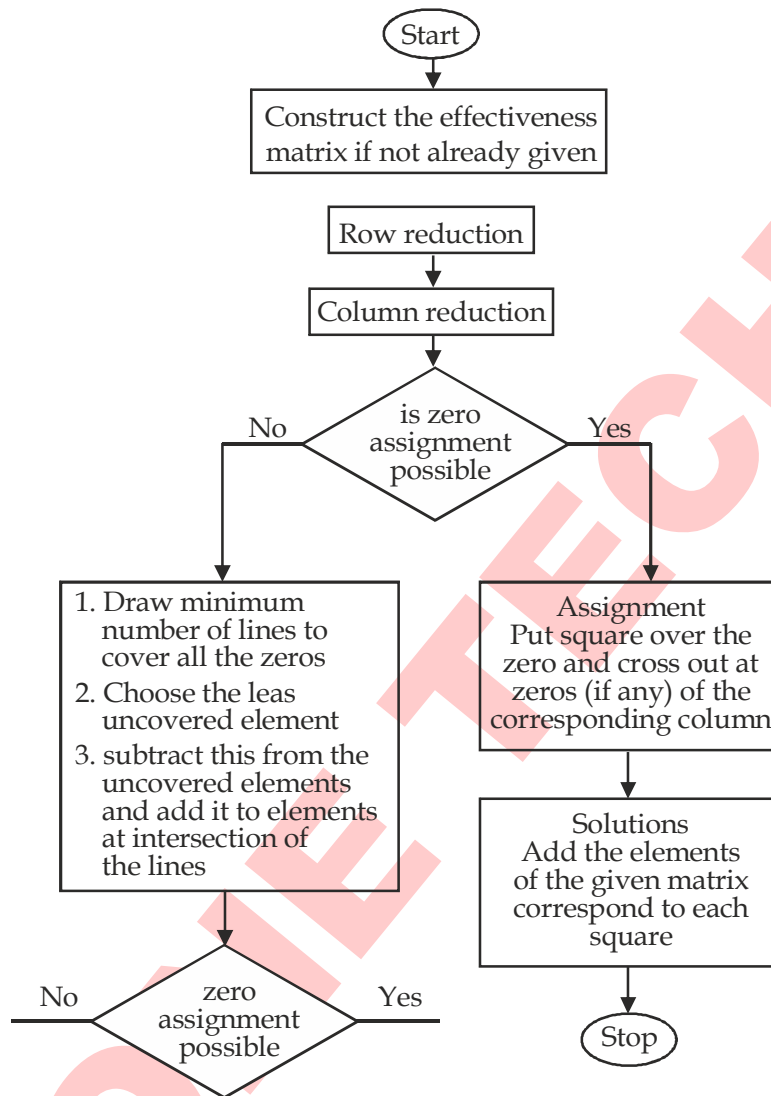
$C_{ij}$  = Unit cost of assigning

$Z$  = Total assignment cost

$X_{ij} = 1$  (If job  $i$  is assigned to operator)

$X_{ij} = 0$  (otherwise)



**Algorithm:**

Hungarian method is used for solving assignment problem. There are two phases in Hungarian method.

**Step 0 :** Consider the given matrix.

**Step 1 :** In a given problem, if the number of rows is not equal to the number of columns and vice versa, then add a dummy row or a dummy column. The assignment cost for dummy cells are always assigned as zero.

**Step 2 :** Reduce the matrix by selecting the smallest element in each row and subtract with other elements in that row.

**Step 3 :** Reduce the new matrix column-wise using the same method as given in step 2.

**Phase 2**

**Step 4 :** Draw minimum number of lines to cover all zeros.

**Step 5 :** If number of lines drawn = order of matrix, then optimality is reached, so proceed to step 7. If optimality is not reached, then go to step 6.

**Step 6 :** Select the smallest element of the whole matrix, which is not covered by lines. Subtract this smallest element from all other remaining elements that are not covered by lines and add the element at the intersection of lines. Leave the elements covered by single line as it is. Now move back to step 4.

**Step 7 :** Take any row or column which has a single zero and assign by a square. Strike off the remaining zeros, if any, in that row and column (x). Repeat the process until all the assignments have been made.

**Step 8 :** Write down the assignment results and find the minimum cost/time.

**Note:** While assigning, if there is no single zero exists in the row or column, choose any one zero and assign it. Strike off the remaining zeros in that column and row and repeat the same for other assignments also. If there is no single zero allocation, it means multiple number of solutions exist. But the cost will remain the same for different sets of allocations.

153.

**Sol.** Number of counters = 5

Each counter's handling capacity = 20/hr =  $\mu$

Arrival rate,  $\lambda = 90/\text{hr}$

**1. The time to serve a request is constant**

Total service capacity of all counters,  $\mu = 5 \times 20 = 100/\text{hr}$

(i) Mean number of persons at any time at this facility,

$$L_s = \frac{\lambda}{\mu - \lambda} = \frac{90}{100 - 90} = \frac{90}{10} = 9$$

(ii) Mean time a person spends at the facility,

$$w_s = \frac{L_s}{\lambda} = \frac{9}{(90/5)} = \frac{9}{18} + 0.5 \text{ hr} = 30 \text{ min}$$

(iii) Average length of queue at each counter,

$$L_q = \left( L_s - \frac{\lambda}{\mu} \right) = \left( 9 - \frac{90}{100} \right) = 8.1$$

**2. The time to serve a request is exponentially distributed**

$\lambda = 90 / \text{hr}$

$\mu = 20 / \text{hr}$  (service rate of individual counter)  $C \rightarrow$  number of counters

$$\rho = \frac{\lambda}{\mu} = \frac{90}{20} = 4.5$$

$$P_0 = \frac{1}{\sum_{n=0}^{c-1} \frac{\left(\frac{\lambda}{\mu}\right)^n}{n!} + \frac{\left(\frac{\lambda}{\mu}\right)^c}{c!} \cdot \frac{c\mu}{c\mu - \lambda}} = \frac{1}{\sum_{n=0}^4 \frac{(4.5)^n}{n!} + \frac{(4.5)^5}{5!} \cdot \frac{5 \times 20}{5 \times 20 - 90}}$$

$$= \frac{1}{1 + \frac{4.5}{1!} + \frac{(4.5)^2}{2!} + \frac{(4.5)^3}{3!} + \frac{(4.5)^4}{4!} + \frac{1}{5!} (4.5)^5 \times \frac{100}{10}} = 4.95 \times 10^{-3}$$

(i) Mean number of persons at any time at this facility

$$L_s = \frac{\lambda \cdot \mu \left(\frac{\lambda}{\mu}\right)^c}{(c-1)!(c\mu - \lambda)} P_0 + \frac{\lambda}{\mu} = \frac{90 \times 20 \times (4.5)^5}{4!(5 \times 20 - 90)^2} \times 4.95 \times 10^{-3} + 4.5$$

$$= 11.35 \approx 12$$

(ii) Mean time a person spends at the facility

$$w_s = \frac{L_q}{\lambda} + \frac{1}{\mu} = \left( \frac{11.35 - 4.5}{90} \right) + \frac{1}{20} = 0.126 \text{ hours} = 7.56 \text{ minutes}$$

(iii) The average length of queue at each counter

$$L_q = L_s - \frac{\lambda}{\mu} = 11.35 - 4.5 = 6.85 \approx 7$$

If the arrival rate becomes 105/hr i.e., more than the service rate of all counter, i.e.,  $5 \times 20 = 100/\text{hr}$ , the system cannot attain a steady state, it is rather unstable, queue length increases steadily with time and theoretically it could build up to infinite. Such a state of system is called explosive state.

154.

Sol. Given data:

$$\eta_{\text{machine}} = 80\%; \text{Scrap} = 25\%$$

Desired output = 1200 pieces per week

In a week = 40 hrs available

In a year = 50 weeks available

$\therefore$  useful component coming out of machine = 75%

Number of component required per year =  $1200 \times 50 = 60000/\text{years}$

Time available =  $40 \times 50 = 2000 \text{ hrs}/\text{years}$

1 hrs.  $\rightarrow$  2 components

Actual components per machine per hour =  $2 \times 0.8 \times 0.75 = 1.2$

Time  $\times$  Component/hr  $\times$  Number of machines = Number of products

$$40 \times 50 \times 1.2 \times N = 1200 \times 50$$

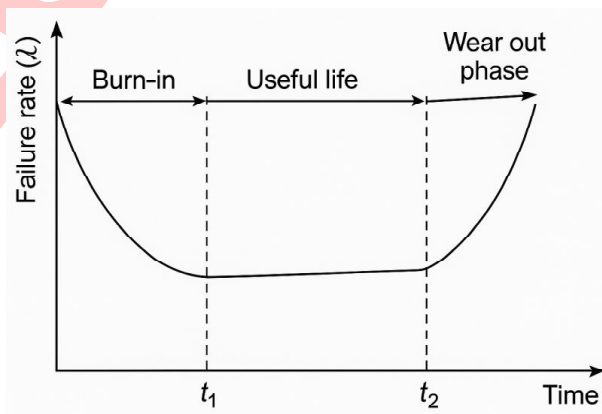
$$\therefore 2000 \times 1.2 \times N = 60000$$

$$N = 25 \text{ machines}$$

155.

Sol. (i) Most products go through three distinct phases from product inception to wear-out. Life cycle curve for failure rate ' $\lambda$ ' can be represented as a function of time. This model is known as bath tub curve which has three phases:

- **Burn in period:** Also known as infant mortality phase or debugging phase. The failure rate decrease in this phase as initial problems identified are ironed out.
- **Useful life period:** In this phase failures occur randomly and independently. Failure rate is constant.
- **Wear out phase:** At the end of useful life components age and wear out. An increase in failure rate is observed.



(ii) Probability density function

Describes the shape and the area of failure distribution.

$$f(t) = \frac{dF(t)}{dt} = -\frac{dR(t)}{dt}$$

$$R(t) = \int_t^0 f(t) dt$$

$$f(t) = \int_0^t f(t) dt$$

For useful life of the product, when failure rate is constant, exponential distribution is used to describe time to failure of the product.

Probability density function (f):

$$f = \lambda e^{-\lambda t}, \quad t \geq 0 \text{ and } \lambda \text{ is the failure rate}$$

Cumulative density function,  $F = \int_0^t e^{-\lambda t} dt$

Reliability at a time  $t$  is given by  $R(t) = 1 - F(t) = 1 - \int_0^t e^{-\lambda t} dt = e^{-\lambda t}$

- (iii) Number of failures = 2  
Total time  $100 \times 20 = 2000$  hrs.

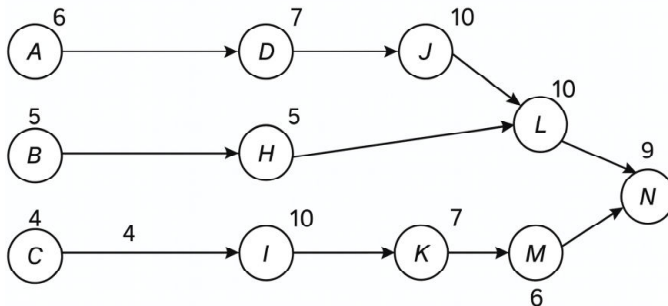
$$\lambda = \frac{1}{\text{MTBF}} = 0.001 / \text{hr.}$$

$$R(t) = e^{-\lambda t}$$

$$R(500) = e^{-0.001 \times 500} = 0.6065$$

156.

Sol.



Listing all the element is decreasing order of their elemental task time :

| Element     | I  | J  | L   | N   | D | G | K | A | H | M | B | E | C | F |
|-------------|----|----|-----|-----|---|---|---|---|---|---|---|---|---|---|
| Time (min.) | 10 | 10 | 10  | 9   | 8 | 7 | 7 | 6 | 6 | 6 | 5 | 5 | 4 | 4 |
| Precedence  | F  | G  | J,H | L,M | A | D | I | - | E | K | - | B | - | C |

| Work Station | Element | Station Time ( $T_{si}$ ) | Idle Time ( $T_c - T_{si}$ ) |
|--------------|---------|---------------------------|------------------------------|
| I            | A-6     | 20                        | 0                            |
|              | B-5     |                           |                              |
|              | E-5     |                           |                              |
|              | C-4     |                           |                              |
| II           | D-8     | 19                        | 1                            |
|              | G-7     |                           |                              |
|              | F-4     |                           |                              |
| III          | I-10    | 20                        | 0                            |
|              | J-10    |                           |                              |
| IV           | K-7     | 19                        | 1                            |
|              | H-6     |                           |                              |
|              | M-6     |                           |                              |
| V            | L-10    | 19                        | 1                            |
|              | N-9     |                           |                              |

Total work duration of all the tasks, (TWC) = 97 min

Cycle time, ( $T_c$ ) = 20 min

$$\text{Number of work stations} = \frac{97}{20} = 4.85$$

∴ The optimal number of work stations = 5

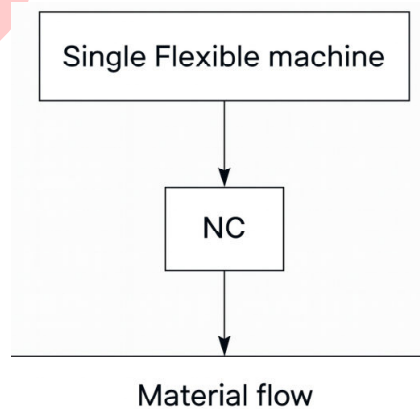
$$\text{Balance delay} = \frac{nT_c - \text{TWC}}{nT_c} = \frac{(5 \times 20) - 97}{100} = 3\%$$

$$\text{Line efficiency} = 1 - \text{BD} = 97\%$$

157.

Sol. (i) **Single manufacturing cell**

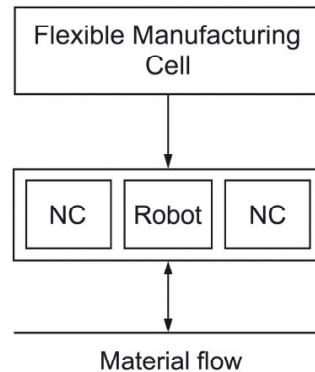
Single Flexible Machine (SFM) or Manufacturing cell is defined as the production unit formed by NC machine, completed by the manipulation facility to change the objects of the production.



(ii) **Flexible manufacturing cell**

Flexible Manufacturing Cell (FMC) is the manufacturing system, created by grouping several NC machines. determined for the certain group of parts with the similar sequence of the operations

or for the certain type of operations. Characteristic sign of the cell is the mutual material and information interconnection among machines.



### (iii) Flexible Manufacturing System

Flexible Manufacturing System (FMS) is understood as the grouping of several manufacturing machines without mutual dependence of their activity, for example AGV transport system. Machines are first of all the machining centres, machines determined for the special operations as to produce the gearing operations and so on. Characteristic sign of their activity are the longer operation times.

