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2. OPERATIONS PLANNING

Q.NO.1. From the following time series data of sale project the sales for the next three years.

Year	2015	2016	2017	2018	2019	2020	2021
Sales (Rs.**000 units)**	80	90	92	83	94	99	92

Q.NO.2. With the help of following data project the trend of sales for the next five years:

Years	2016	2017	2018	2019	2020	2021
Sales (in lakhs)	100	110	115	120	135	140

Q.NO.3. An investigation into the demand for colour TV sets in 5 towns has resulted in the following data:

Population of the town (in lakhs)	X:	5	7	8	11	14
No of TV sets demanded (in thousands)	Y:	9	13	11	15	19

Fit a linear regression of Y on X and estimate the demand for CTV sets for two towns with a population of 10 lakhs and 20 lakhs.

Q.NO.4. An investigation into the use of scooters in 5 towns has resulted in the following data: Population in town

Population in town (in lakhs)	(X)	4	6	7	10	13
No. of scooters	(Y)	4,400	6,600	5,700	8,000	10,300

Fit a linear regression of Y on X and estimate the number of scooters to be found in a town with a population of 16 lakhs.

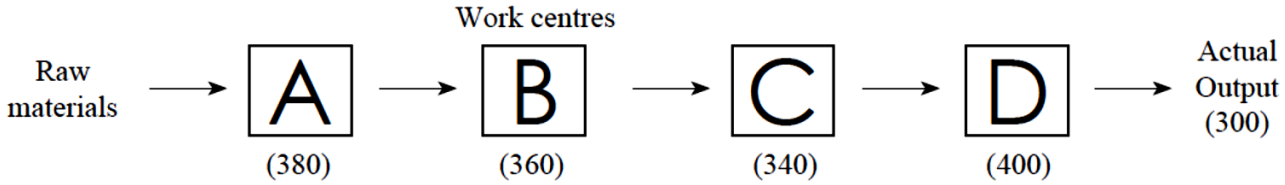
Q.NO.5. A department works on 8 hours shift, 250 days a year and has the usage data of a machine, as given below:

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

Determine the number of machines required.

Q.NO.6. A steel plant has a design capacity of 50,000 tons of steel per day, effective capacity of 40,000 tons of steel per day and an actual output of 36,000 tons of steel per day. Compute the efficiency of the plant and its utilisation.

Q.NO.7. A firm has four work centres, A, B-n, C & D, in series with individual capacities in units per day shown in the figure below.



(i) Identify the bottle neck centre.

(ii) What is the system capacity?

(iii) What is the system efficiency?

Q.NO.8. A manager has to decide about the number of machines to be purchased. He has three options i.e., purchasing one, or two or three machines. The data are given below.

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

Variable cost is Rs. 20 per unit and revenue is Rs. 50 per unit

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

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

Q.NO.9. Suppose, an E-Commerce company wants to open Central order fulfilment center in Kolkata South in West Bengal. The possible locations are say L1, L2, and L3. The company form a group of experts. The team identifies say 6 actors such as F1, F2, F3, and F4 to evaluate L1 to L3.

Q.NO.10. Suppose, XYZ Ltd wants to open a retail shop in Kolkata, West Bengal.

It first selects the 4 locations such as L1, L2, L3 and L4. The coordinates of the locations (i.e., latitudes and longitudes) and volume of customers (i.e., average number of customers in a day in '000) are given in the following table

		Coordinates	
Location	**Volume**	**X**	**Y**
L_1	200	30	100
L_2	100	90	120
L_3	100	130	130
L_4	200	60	40

Find out the best location using Center of Gravity (COG) method.

Q.NO.11. The present layout is shown in the figure. The manager of the department is intending to interchange the departments C and F in the present layout. The handling frequencies between the departments is given. All the departments are of the same size and configuration. The material handling cost per unit length travel between departments is same. What will be the effect of interchange of departments C and F in the layout?

A	C	E
B	D	F

From / To	A	B	C	D	E	F
A	–	0	90	160	50	0
B	–	–	70	0	100	130
C	–	–	20	0	0	

From / To	A	B	C	D	E	F
D	–	–	–	_	180	10
E	–	–	–	–	40	
F	–	–	–	–	–	–

Q.NO.12. A defence contractor is evaluating its machine shops current process layout. The figure below shows the current layout and the table shows the trip matrix for the facility. Health and safety regulations require departments E and F to remain at their current positions.

E	B	F
A	C	D

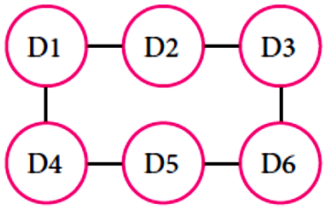
Current Layout

From / To	A	B	C	D	E	F
A		8	3		9	5
B		-		3		
C			-		8	9
D		-				3
E					-	3
F						-

Can layout be improved? Also evaluate using load distance (ld) score.

Q.NO.13. Suppose a hospital has 6 major departments namely D1, D2, D3, D4, D5 and D6. The initial layout of the hospital is given below.

Initial Layout



The average traffic movement to and fro each department is given in the following table

Table – Average traffic flow (Direct)

	D1	D2	D3	D4	D5	D6
D1	–	10	20	0	5	6
D2	8	–	6	10	0	2
D3	10	6	–	20	7	8
D4	0	25	5	–	10	3
D5	15	10	1	20	–	6
D6	0	6	0	3	4	–

The hospital wants to find out an optimum layout.

Q.NO.14. ABC. Co. has developed a forecast for the group of items that has the following demand pattern

Quarter	Demand	Cumulative demand
1	270	270
2	220	490
3	470	960
4	670	1630
5	450	2080
6	270	2350
7	200	2550
8	370	2920

The firm estimates that it costs Rs. 150 per unit to increase production rate Rs. 200 per unit to decrease the production rate, Rs. 50 per unit per quarter to carry the items in inventory and Rs.100 per unit if subcontracted. Compare the costs of the pure strategies.

Q.NO.15. A firm has developed the following forecast (units) for an item which has a demand influence by seasonal factors.

Month	Forecasted Demand	Production Days
Jan	220	22
Feb	90	18
Mar	210	21
Apr	396	22
May	616	22
Jun	700	20
Jul	378	21
Aug	220	22
Sep	200	20
Oct	115	23
Nov	95	19
Dec	260	20

(a) Prepare a chart showing the daily demand requirements.

(b) Determine the production rate required to meet average demand.

(c) Determine the monthly inventory balance required to follow a plan with:

1. Constant workforce

2. No idle time or overtime

3. No Backorder

4. No use of Sub-Contractor

5. No capacity adjustment

(d) The firm has determined that to follow a plan of meeting demand by varying the size of the workforce strategy

Put result in hiring and lay-off cast estimated at Rs.12000. If the unit cost is Rs.100 each to produce, carrying cost per year are 20% of the average inventory value and storage cost (based upon maximum inventory) are Rs.0.90 per unit which plan results in the lower cost, varying inventory or varying employment? [Where Plan 1 indicates varying inventory and Plan 2 indicates varying Employment]

(e) Suppose the firm wishes to investigate two other plans (alternatives). A third plan is to produce at a rate of 10 units per day and sub-contract the additional requirements at a delivered cost of Rs.107 per unit.

Any accumulated inventory is carried forward at a 20% carrying cost (No extra Storage cost).

The Fourth Plan is to produce at a steady rate of 10 units per day and use overtime to meet the additional requirement at a premium of Rs.10 per unit. Accumulated inventory is again carried forward at a 20% cost.

(f) Compare 4 plans given in Question (d) and (e) and comment which plan gives the minimum cost.

Q.NO.16. The monthly requirement of raw material for a company is 3000 units. The carrying cost is estimated to be 20% of the purchase price per unit, in addition to Rs. 2 per unit. The purchase price of raw material is Rs. 20 per unit. The ordering cost is Rs. 25 per order. (i) You are required to find EOQ.(ii) What is the total cost when the company gets a concession of 5% on the purchase price if it orders 3000 units or more but less than 6000 units per month. (iii) What happens when the company gets a concession of 10% on the purchase price when it orders 6,000 units or more? (iv) Which of the above three ways of orders the company should adopt?

Q.NO.17. M/s. Tubes Ltd. are the manufacturers of picture tubes of T.V. The following are the details of their operation during 2001:

Average monthly market demand	2,000 tubes
Ordering cost	Rs. 100 per order
Inventory carrying cost	20% per annum
Cost of tubes	Rs. 500 per tube
Normal usage	100 tubes per week
Minimum usage	50 tubes per week
Maximum usage	200 tubes per week
Lead time to supply	6 – 8 weeks

Compute from the above:

(1) Economic order quantity. If the supplier is willing to supply quarterly 1,500 units at a discount of 5%, is it worth accepting?

(2) Maximum level of stock.

(3) Minimum level of stock.

(4) Re-order level of stock.

Q.NO.18. M/s Kobo Bearings Ltd., is committed to supply 24,000 bearings per annum to M/s Deluxe Fans on a steady daily basis. It is estimated that it costs 10 paisa as inventory holding cost per bearing per month and that the setup cost per run of bearing manufacture is Rs. 324.

(a) What is the optimum run size for bearing manufacture?

(b) What should be the interval between the consecutive optimum runs?

(c) Find out the minimum inventory holding cost.

Q.NO.19. A company planning to manufacture a household cooking range has to decide on the location of the plant. Three locations are being considered viz., Patna, Ranchi, and Dhanbad. The fixed costs of the three location are estimated to be Rs.30 lakh, Rs.50 lakh, and Rs.25 lakh per annum respectively. The variable costs are Rs.300, Rs.200 and Rs.350 per unit respectively.

The expected sales price of the cooking range is Rs.700 per unit Find out:

(i) The range of annual production/sales volume for which each location is most suitable and

(ii) Which one of the three locations is the best location at a production/sales volume of 18,000 units?

Q.NO.20. Monthly demand for a component is 1000 units. Setting-up cost per batch is Rs. 120. Cost of manufacture per unit is Rs. 20. Rate of interest may be considered at 10% p.a. Calculate the EBQ.

Q.NO.21. Based on the following data on the exports of an item by a company during the various years fit a straight line, (for the time being, assume that a straight line gives a good fit). Give a forecast for the years 2013 and 2014.

Year	No. of items ('000)
2004	13
2005	20
2006	20
2007	28
2008	30
2009	32
2010	33
2011	38
2012	43

Q.NO.22. Find the economic order quantity and the reorder point, given

Annual demand (D) = 1000 units

Average daily demand (d) = 1000/365

Ordering Cost (S) = Rs. 5 per order

Holding cost(H) = Rs. 1.25 per unit per year.

Lead time (L) = 5 days

Cost per unit (C) = Rs. 12.50

What quantity should be ordered?

Q.NO.23. Consider an economic order quantity case where annual demand D=1000 units, economic order quantity Q= 200 units , the desired probability of not stocking out P=0.95 , the standard deviation of demand during lead time 6L =25units and lead time = L=15 days. Determine the reorder point. Assume the demand is over a 250 week day year.

Q.NO.24. Daily demand for a certain product is normally distributed with a mean of 60 and standard deviation of 7. The source of supply is reliable and maintain a constant lead time of six days. The cost of placing the order is Rs.10 and annual holding costs are Rs.0.50 per unit. There are no stock out costs, and unfilled orders are filled as soon as the order arrives. Assume sales occur over the entire 365 days of the year. Find the order quantity and reorder point to satisfy a 95 percent probability of not stocking out during the lead time.

Q.NO.25. Fixed -Time period Model with safety stock

Daily demand for a product is 10 units with a standard deviation of 3 units. The review period is 30 days, and lead time is 14 days. Management has set a policy of satisfying 98% of demand from items in stock. At the beginning of this review period, there are 150 units in inventory.

Q.NO.26. Average Inventory calculation – Fixed order quantity model

Suppose the following item is being managed using a fixed order quantity model with safety stock

Annual Demand (D) = 1000 units

Order quantity (Q) = 300 units

Safety stock (SS) = 40 units

What are the average inventory level and inventory turn for the item?

Q.NO.27. Average Inventory calculation – Fixed Time period model

Consider the following item that is being managed using a fixed time period model with safety stock

Weekly demand (d) = 50 units

Review cycle (T) = 3 weeks

Safety stock (SS) = 30 units

What are the average inventory level and inventory turn for the item?

Q.NO.28. Price Break Problem

Consider the following case, where

D = 10000 units (annual demand)

S = Rs. 20 to place order

I = 20 percent of cost (annual carrying cost, storage, interest, obsolescence, etc)

C = Cost per unit (according to the order size: order of 0 to 499 units, Rs.5.00 per unit; 500 to 999 units, Rs.4.50 per unit; 1000 and up, Rs.3.90 per unit)

What quantity should be ordered?

Q.NO.29. A product is priced to sell at Rs.100 per unit, and its cost is constant at Rs.70 per unit. Each unsold unit has a salvage value of Rs.20. Demand is expected to range between 35 and 40 units for the period. 35 definitely can be sold and no units over 40 will be sold. The demand probabilities and the associated cumulative probability distribution (P) for this situation fo;;ow.

Number of Units	Demanded Probability of this Demand	Cumulative Probability
35	0.10	0.10
36	0.15	0.25
37	0.25	0.50
38	0.25	0.75
39	0.15	0.90
40	0.10	1.00

How many units should be ordered?

Q.NO.30. A company currently has 200 units of a product on hand that it orders every two weeks when the salesperson visits the premises. Demand for the product averages 20 units per day with a standard deviation of 5 units.

Lead time for the product to arrive is seven days. Management has a goal of 95 percent probability of not stocking out for this product. The salesperson is due to come in late this afternoon when 180 units are left in stock (assuming that 20 are sold today). How many units should be ordered?

Q.NO.31. Solve the ABC analysis of the following table and show graphically taking Percentage of total list of different stock items as x axis and Percentage of total inventory value along y axis

Annual Usage if Inventory by Value

Item Number	Annual Rupee Usage (Rs.)	Percentage of total value (%)
22	95000	40.69
68	75000	32.13
27	25000	10.71
03	15000	6.43
82	13000	5.57
54	7500	3.21

36	1500	0.64
19	800	0.34
23	425	0.18
41	225	0.10
TOTAL	Rs. 233450	100%

4. APPLICATION OF OPERATION RESEARCH - PRODUCTION PLANNING AND CONTROL

Q.NO.1. A Chemical Company produces two compounds A and B. The following table gives the units of ingredients C and D per kg of compounds A and B as well as minimum requirements of C and D and costs/kg of A and B. Write drawn the problem mathematically for minimisation of cost.

		Table Compound		**Minimum requirement**
		A	B	
Ingredient	C	1	2	80
	D	3	1	75
Cost per kg.		4	6	

Q.NO.2. A pension fund manager is considering investing in two shares A and B. It is estimated that:

(i) Share A will earn a dividend of 12% per annum and share B 4% per annum.

(ii) Growth in the market value in one year of share A will be 10 paise per Rs.1 invested and in B 40 paise per Rs.1 invested.

He requires investing the minimum total sum which will give:

Dividend income of at least Rs.600 per annum and growth in one year of at least Rs.1,000 on the initial investment.

You are required to:

State the mathematical formulation of the problem which will facilitate computation of the minimum sum to be invested to meet the manager's objective.

Q.NO.3. A company possesses two manufacturing plants each of which can produce three products X, Y and Z from a common raw material. However, the proportions in which the products are produced are different in each plant and so are the plant's operating costs per hour. Data on production per hour costs are given below, together with current orders in hand for each product.

	Product			**Operating cost/hour in Rs.**
	X	Y	Z	
Plant A	2	4	3	9
Plant B	4	3	2	10
Orders on hand	50	24	60	

You are required to formulate the problem to find the number of production hours needed to fulfill the orders on hand at minimum cost.

Q.NO.4. The products P, Q and R are being produced in a plant having profit margin as Rs. 3, Rs. 5 and Rs. 4 respectively. The raw materials A, B and C are of scarce supply and the availability is limited to 8, 15 and 10 units respectively.

Specific consumption is indicated in the table below:

	P	**Q**	**R**	**Available units**
A	2	3	–	8
B	3	2	4	15
C	-	2	5	10
	3/-	5/-	4/-	

Write down the problem mathematically for maximization of profit margin.

Q.NO.5. A Bank is in the process of formulating its loan policy. Involving a maximum of Rs. 600 Million. Table below gives the relevant types of loans. Bad debts are not recoverable and produce no interest receive. To meet competition from other Banks the following policy guidelines have been set. At least 40% of the funds must be allocated to the agricultural and commercial loans. Funds allocated to housing must be at least 50% of all loans given to personal, car, Housing. The overall bad debts on all loans may not exceed 0.06.

Formulate a linear program Model to determine optimal loan allocations.

Type of loan	**Interest rate %**	**Bad debts (Probability)**
Personal	17	0.10
Car	14	0.07
Housing	11	0.05
Agricultural	10	0.08
Commercial	13	0.06

Q.NO.6. The annual hand-made furniture show and sales occurs next month and the school of vocational studies is planning to make furnitures for sale. There are three wood working classes – I year, II year, III year at the school and they have decided to make three styles of chairs A, B and C. Each chair must receive work in each class and the time in hours for each chair in each class is given.

Chair	I year	II year	III year
A	2	4	3
B	3	3	2
C	2	1	4

In the next month there will be 120 hours available in first year class, 160 hours in the second year class and 100 hours in the third year class to produce chairs. The teacher of the wood working class feels that a maximum of 40 chairs can be sold at the show. The teacher has determined that the profit from each type of chair will be A – Rs.40, B – Rs.35 and C – Rs.30.

Formulate a linear programming model to determine how many chairs should be produced to maximize profit.

Q.NO.7. A company produces three products P, Q and R from three raw materials A, B and C. One unit of product P requires 2 units of A and 3 units of B. One unit of product Q requires 2 units of B and 5 units of C and one unit of product R requires 3 units of A, 2 units of B and 4 units of C. The company has 8 units of material A, 10 units of material B and 15 units of material C available to it. Profits per unit of products P, Q and R are Rs. 3, Rs. 5 and Rs.4 respectively.

Formulate the question mathematically to maximize the profit.

Q.NO.8. A city hospital has the following minimal daily requirement for nurses:

Period	Clock time (24 hours day)	Minimal Number of Nurses Required
1	6 a.m. - 10 a.m.	2
2	10 a.m. - 2 p.m.	7
3	2 p.m. - 6 p.m.	75
4	6 p.m. - 10 p.m.	8
5	10 p.m. - 2 a.m.	20
6	2 a.m. - 6 a.m.	6

Nurses report to the hospital at the beginning of each period and work for 8 consecutive hours. The hospital wants to determine the minimal number of nurses to be employed so that there will be sufficient number of nurses available for each period.

Formulate this as a Linear Programming question by setting up appropriate constraints and objective function.

Q.NO.9. A marketing manager wishes to allocate his annual advertising budget of Rs. 20,000 in two media vehicles A and B. The unit cost of a message in media A is Rs. 1,000 and that of B is Rs. 1,500. Media A is a monthly magazine and not more than one insertion is desired in one issue. At least 5 messages should appear in media B. The expected effective audience for unit messages in the media A is 40,000 and for media B is 55,000.

(i) Develop a mathematical model

Q.NO.10. One unit of product A contributes Rs. 7 and requires 3 units of raw material and 2 hours of labour. One unit of product B contributes Rs. 5 and requires one unit of raw material and one hour of labour. Availability of raw material at present is 48 units and hence there are 40 hours of labour.

i. Formulate it as a linear programming problem.

ii. Write its dual.

Q.NO.11. A Company produces the products P, Q and R from three raw materials A, B and C. One unit of product P requires 2 units of A and 3 units of B. A unit of product Q requires 2 units of B and 5 units of C and one unit of product R requires 3 units of A, 2 unit of B and 4 units of C. The Company has 8 units of material A, 10 units of B and 15 units of C available to it. Profits/unit of products P, Q and R are Rs.3, Rs.5 and Rs.4 respectively.

(a) Formulate the problem mathematically,

(b) Write the Dual problem.

Q.NO.12. Four Products A,B,C and D have Rs. 5, Rs. 7, Rs. 3 and Rs. 9 profitability respectively. First type of material (limited supply of 800 kgs.) is required by A,B,C and D at 4 kgs., 3 kgs, 8 kgs, and 2 kgs. respectively per unit.

Second type of material has a limited supply of 300 kgs. and is for A,B,C and D at 1 kg, 2 kgs, 0 kgs, and 1 kg per unit. Supply of the other type of materials consumed is not limited. Machine hrs. available are 500 hours and the requirements are 8,5,0 and 4 hours for A,B,C and D each per unit.

Labour hours are limited to 900 hours and requirements are 3,2,1 and 5 hours for A,B,C and D respectively.

How should the firm approach so as to maximize its profitability? Formulate this as a linear programming problem. You are not required to solve the LPP.

Q.NO.13. Mutual Fund has cash resources of Rs. 200 million for investment in a diversified portfolio. Table below shows the opportunities available, their estimated annual yields, risk factor and term period details.

Formulate a Linear Program Model to find the optimal portfolio that will maximize return, considering the following policy guidelines:

- All the funds available may be invested
- Weighted average period of at least five years as planning horizon.
- Weighted average risk factor not to exceed 0.20.
- Investment in real estate and speculative stocks to be not more than 25% of the monies invested in total.

Investment type	Annual yield (percentage)	Risk factor	Term period (years)
Bank deposit	9.5	0.02	6
Treasury notes	8.5	0.01	4
Corporate deposit	12.0	0.08	3
Blue-chip stock	15.0	0.25	5
Speculative stocks	32.5	0.45	3
Real estate	35.0	0.40	10

Q.NO.14. What is the slope of the objective function Max Z = 15*X* + 45*Y*?

Q.NO.15. An electronic goods manufacture has distributors who will accept shipments of either transistor radios or electronic calculators to stock for Christmas inventory Whereas the radios contribute Rs.10 per unit and the calculator Rs.15 per unit to profits, both products use some of the same components. Each radio requires each of diodes and resistors, while each calculator requires 10 diodes and 2 resistors. The radio take 12.0 minutes and the calculators take 9.6 minutes of time on the company's electronic testing machine, and the production manager estimates that 160 hours of test time is a available. The firm has 8,000 diodes and 3,000 resistors in inventory. What product of mix of products should be selected to obtain the highest profit?

Q.NO.16. The simplex calculator company makes a profit of Rs.5 on each model X and Rs.20 on each model Y. Each calculator requires the following time (in minutes) on the cleaning and testing machines.

	X Requirements	Y Requirements	Time Available
Cleaning Testing	2 6	4 3	10 12

(a) State the objective function and constraints.

(b) Arrange the equations in a simplex format.

Q.NO.17. The initial matrix of a maximization linear programming problem is as shown where the decision variables are designated A, B, etc.

C→ ↓		4	8	6	0	0	0	RHS
	Variables	5	9	0	1	0	0	36
	in solution	0	8	5	0	1	0	24
		2	0	5	0	0	1	7
		0	0	0	0	0	0	
		4	8	6	0	0	0	0

(a) State the original constraint equations.

(b) How many decision variables are there?

(c) State the objective function.

Q.NO.18. The cost conscious company requires for the next month 300, 260 and 180 tonnes of stone chips for its three constructions C1, C2 and C3 respectively. Stone chips are produced by the company at three mineral fields taken on short lease by the company. All the available boulders must be crushed into chips. Any excess chips over the demands at sites C1, C2 and C3 will be sold ex-fields.

The fields are M1, M2 and M3 which will yield 250, 320 and 280 tones of stone chips respectively.

Transportation costs from mineral fields to construction sites vary according to distances, which are given below in monetary unit (MU).

	To	C1	C2	C3
From	M1	8	7	6
	M2	5	4	9
	M3	7	5	5

(i) Determine the optimal economic transportation plan for the company and the overall transportation cost in MU.

(ii) What are the quantities to be sold from M1, M2 and M3 respectively?

Q.NO.19. Ladies fashion shop wishes to purchase the following quantity of summer dresses:

Dress size	I	II	III	IV
Quantity	100	200	450	150

Three manufacturers are willing to supply dresses.

The quantities given below are the maximum that they are able to supply of any given combination of orders for dresses:

Manufacturers	A	B	C
Total quantity	150	450	250

The shop expects the profit per dress to vary with the manufacturer as given below:

Size

	I	**II**	**III**	**IV**
A	Rs.2.5	Rs.4.0	Rs.5.0	Rs.2.0
B	Rs.3.0	Rs.3.5	Rs.5.5	Rs.1.5
C	Rs.2.0	Rs.4.5	Rs.4.5	Rs.2.5

Required:

(a) Use the transportation technique to solve the problem of how the orders should be placed with the manufacturers by the fashion shop is order to maximise profit.

(b) Explain how you know there is no further improvement possible.

Q.NO.20. The products of three plants F1, F2 and F3 are to be transported to 5 warehouses W1, W2, W3, W4 and W5. The capacities of plants, demand of warehouses and the cost of transportation from one plant to various warehouses are indicated in the following table:

	W1	**W2**	**W3**	**W4**	**W5**	**Plant Capacity**
F1	74	56	54	62	68	400
F2	58	64	62	58	54	500
F3	66	70	52	60	60	600
Warehouse Demand	200	280	240	360	320	1500/1400

(a) Find out a distribution plan of products from plants to the warehouses at a minimum cost. What is the minimum cost?

(b) Is there any surplus capacity of the plants? If so, in which plant should we associate that surplus capacity?

(c) Is there any alternate solution for the optimum solution achieved in

Q.NO.21. A company has 4 factories F1, F2, F3, & F4 manufacturing the same product. Production & row material cost differ from factory to factory and are given in the following table in the first two rows.

The transportation cost from factories to sales departments S_1, S_2, S_3, are also given. The last two columns in the table give the sales price & the total requirement at each sales department.

The production capacity of each factory is given in the last row.

Factories

Sales Dept.

Factories **Sales Dept.**	**F_1**	**F_2**	**F_3**	**F_4**	**Sales price/unit**	**Requirement**
Production cost/unit	15	18	14	13		
Row material cost/unit	10	9	12	9		
Transportation Cost/unit S_1	3	9	5	5	34	80
S_2	1	7	4	5	32	120
S_3	5	8	3	6	31	150
Availability	10	150	50	100		

Determine the most profitable production & the distribution schedule & the corresponding profit. The surplus product should be taken to yield zero profit.

Q.NO.22. Departmental store wishes to purchase the following quantities of Sprees:

Types of sprees	**A**	**B**	**C**	**D**	**E**
Quantity	150	100	75	250	200

Tenders are submitted by 4 different manufacturers who undertake to supply not more than the quantities mentioned below (all types of sprees combined):

Manufacturer	**W**	**X**	**Y**	**Z**
Total quantity	300	250	150	200

The store estimates that its profit/spree will vary with the manufacturer as shown in the following matrix.

Manufacturers	Sprees				
	A	B	C	D	E
W	275	350	425	225	150
X	300	325	450	175	100
Y	250	350	475	200	125
Z	325	275	400	250	175

How should the orders be placed?

Q.NO.23. The Bombay Transport Company has trucks available at four different sites in the following numbers:

Site A 5 Trucks

Site B 10 Trucks

Site C 7 Trucks

Site D 3 Trucks

Customers – W, X and Y require trucks as shown below.

Customer W 5 Trucks

Customer X 8 Trucks

Customer Y 10 Trucks

Variable Costs of getting trucks to the Customers are given below:

From A to W	Rs. 7, to X	Rs. 3, to Y	Rs. 6
From B to W	Rs. 4, to X	Rs. 6 to Y	Rs. 8
From C to W	Rs. 5, to X	Rs. 8 to Y	Rs. 4
From D to W	Rs. 8 to X	Rs. 4 to Y	Rs. 3

Solve the above transportation problem.

Q.NO.24. A company has 3 plants located at different places but producing an identical product. The cost of production, distribution cost of each plant to the 3 different warehouses, the sale price at each warehouse and the individual capacities for both the plant and warehouse are given below:

Plants	F1	F2	F3		
Raw material	15	18	14		
Other expenses	10	9	12		

Distribution cost to warehouse				Sales Price in (Rs.)	Warehouse Capacity (No)
W1	3	9	5	34	80
W2	1	7	4	32	110
W3	5	8	3	31	150
Capacity of Plant (No.)	150	100	130		

Establish a suitable table giving net profit/loss for a unit produced at different plants and distributed at different locations.

(a) Introduce a suitable dummy warehouse / plant so as to match the capacities of plants and warehouses.

(b) Find distribution pattern so as to maximise profit / minimise loss.

(c) Interpret zero value of square evaluation of an empty cell and find alternative solutions.

Q.NO.25. Six men are available for different jobs. From past records the time in hours taken by different persons for different jobs are given below.

	Jobs						
Men	1	2	3	4	5	6	
	1	2	9	2	7	9	1
	2	6	8	7	6	14	1
	3	4	6	5	3	8	1
	4	4	2	7	3	10	1
	5	5	3	9	5	12	1
	6	9	8	12	13	9	1

Find out an allocation of men to different jobs which will lead to minimum operation time.

Q.NO.26. A captain of a cricket team has to allot five middle batting positions to five batsmen. The average runs scored by each batsman at these positions are as follows:

Batting Position						
Batsmen						
		III	**IV**	**V**	**VI**	**VII**
	A	40	40	35	25	50

	B	42	30	16	25	27
	C	50	48	40	60	50
	D	20	19	20	18	25
	E	58	60	59	55	53

Make the assignment so that the expected total average runs scored by these batsmen are maximum.

Q.NO.27. Average time taken by an operator on a specific machine is tabulated below. The management is considering replacing one of the old machines by a new one and the estimated time for operation by each operator on the new machine is also indicated.

Operator	**Machines**						
	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**New**
01	2	3	2	1	4	5	6
02	4	4	6	3	2	5	1
03	6	10	8	4	7	6	1
04	8	7	6	5	3	9	4
05	7	3	4	5	4	3	12
06	5	5	6	7	8	1	6

(a) Find out an allocation of operators to the old machines to achieve a minimum operation time.

(b) Reset the problem with the new machine and find out the allocation of the operators to each machine and comment on whether it is advantageous to replace an old machine to achieve a reduction in operating time only.

(c) How will the operators be reallocated to the machines after replacement?

Q.NO.28. Six salesmen are to be allocated to six sales regions so that the cost of allocation of the job will be minimum.

Each salesman is capable of doing the job at different cost in each region. The cost matrix is given below:

Salesmen							**Region**
		I	**II**	**III**	**IV**	**V**	**VI**
	A	15	35	0	25	10	45

	B	40	5	45	20	15	20
	C	25	60	10	65	25	10
	D	25	20	35	10	25	60
	E	30	70	40	5	40	50
	F	10	25	30	40	50	15

(Figures are in Rupees)

(a) Find the allocation to give minimum cost. What is the minimum cost?

(b) Now suppose the above table gives earning of each salesman at each region. How can you find an allocation so that the earning will be maximum? Determine the solution with optimum earning.

(c) There are restrictions for commercial reasons that A cannot be posted to region V and E cannot be posted to region II. Write down the cost matrix suitably after imposing the restrictions.

Q.NO.29. Four jobs can be processed on four different machines, with one job on one machine. Resulting profits vary with assignments. They are given below:

Machines					
Jobs		**A**	**B**	**C**	**D**
	I	42	35	28	21
	II	30	25	20	15
	III	30	25	20	15
	IV	24	20	16	12

Find the optimum assignment of jobs to machines and the corresponding profit.

Q.NO.30. A salesman has to visit five cities A, B, C, D and E. The inter-city distances are tabulated below. Note the distance between two cities need not be same both ways.

From / To	**A**	**B**	**C**	**D**	**E**
A	-	12	24	25	15
B	6	--	16	18	7
C	10	11	--	18	12
D	14	17	22	--	16
E	12	13	23	25	--

Note further that the distances are in km.

Required:

If the salesman starts from city A and has to come back to city A, which route would you advise him to take so that total distance traveled by him is minimised?

Q.NO.31. The processing times (tj) in hrs for the five jobs of a single machine scheduling is given. Find the optimal sequence which will minimise the mean flow time and find the mean flow time.

Determine the sequence which will minimise the weighted mean flow time and also find the mean flow time

Job (j)	1	2	3	4	5
Processing time (tj) hrs	30	8	10	28	16
Weight (Wj)	1	2	1	2	3

Q.NO.32. Customers arrive at a bakery at an average rate of 16 per hour on weekday mornings. The arrival can be described by a Poisson distribution with a mean of 16. Each clerk can serve a customer in an average of three minutes; This time can be described by an exponential distribution with a mean of 3.0 minutes.

a. What are the arrival and service rates?

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

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

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

Q.NO.33. An airline is planning to open a satellite ticket desk in a new shopping plaza, staffed by one ticket agent. It is estimated that requests for tickets and information will average 15 per hour, and requests will have a Poisson distribution. Service time is assumed to be exponentially distributed. Previous experience with similar satellite operations suggests that mean service time should average about three minutes per request.

Determine each of the following:

a. System utilization.

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

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

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

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

Q.NO.34. Wanda's Car Wash & dry is an automatic, five-minute operation with a single bay. On a typical Saturday morning, cars arrive at a mean rate of eight per hour, with arrivals tending to follow a Poisson distribution. Find a. The average number of cars in line.

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

Q.NO.35. A departmental store has one cashier. During the rush hours, customers arrive at a rate of 20 per hour. The average number of customers that can be handled by the cashier is 24 per hour. Assume the conditions for use of the single – channel queuing model. Find out average time a customer spends in the system.

Illustration 36

Q.NO.36. As a tool service centre the arrival rate is two per hour and the service potential is three per hour. Simple queue conditions exist.

The hourly wage paid to the attendant at the service centre is Rs.1.50 per hour and the hourly cost of a machinist away from his work is Rs. 4.

Calculate:

(i) The average number of machinists being served or waiting to be served at any given time.

(ii) The average time a machinist spends waiting for service.

(iii) The total cost of operating the system for an eight – hour day.

(iv) The cost of the system if there were two attendants working together as a team, each paid Rs. 1.50 per hour and each able to service on average 2 per hour.

Q.NO.37. Workers come to tool store room to enquire about special tools (required by them) for accomplishing a particular project assigned to them. The average time between two arrivals is 60 seconds and the arrivals are assumed to be in Poisson distribution. The average service time (of the tool room attendant) is 40 seconds.

Determine:

(i) average queue length,

(ii) average length of non-empty queues,

(iii) average number of workers in system including the worker being attended

(iv) mean waiting time of an arrival,

(v) average waiting time of an arrival who waits.

Q.NO.38. State the major two reasons for using simulation to solve a problem A confectioner sells confectionery items. Past data of demand per week in hundred kilograms with frequency is given below:

Demand/Week	0	5	10	15	20	25
Frequency	2	11	8	21	5	3

Using the following sequence of random numbers, generate the demand for the next 10 weeks. Also find out the average demand per week.

Random numbers	35	52	13	90	23	73	34	57
	35	83	94	56	67	66	60	

Q.NO.39. The manager of a book store has to decide the number of copies of a particular tax law book to order. A book costs Rs. 60 and is sold for Rs. 80. Since some of the tax laws change year after year, any copies unsold while the edition is not current must be sold for Rs. 30. From past records, the distribution of demand for this book has been obtained as follows:

Demand (No of copies)	15	16	17	18	19	20	21	22
Proportion	0.05	0.08	0.20	0.45	0.10	0.07	0.03	0.02

Using the following sequence of random numbers, generate the demand for 20 time periods(years). Calculate the average profit obtainable under each of the courses of action open to the manager. What is the optimal policy?

14	02	93	99	18	71	37	30	12	10
88	13	00	57	69	32	18	08	92	73

Q.NO.40. A Small retailer has studied the weekly receipts and payments over the past 200 weeks and has developed the following set of information:

Weekly Receipts (Rs.)	**Probability**	**Weekly Payments (Rs.)**	**Probability**
3000	0.20	4000	0.30
5000	0.30	6000	0.40
7000	0.40	8000	0.20

12000	0.10	10000	0.10

Using the following set of random numbers, simulate the weekly pattern of receipts and payments for the 12 weeks of the next quarter, assuming further that the beginning bank balance is Rs. 8000. What is the estimated balance at the end of the 12 weekly period? What is the highest weekly balance during the quarter? What is the average weekly balance for the quarter?

Random Numbers

For Receipts	03	91	38	55	17	46	32	43	69	72	24	22
For payments	61	96	30	32	03	88	48	28	88	18	71	99

According to the given information, the random number interval is assigned to both the receipts and the payments.

Q.NO.41. An automobile production line turns out about 100 cars a day, but deviations occur owing to many causes. The production is more accurately described by the probability distribution given below:

Production/Day	Prob.	Production/Day	Prob.
95	0.03	101	0.15
96	0.05	102	0.10
97	0.07	103	0.07
98	0.10	104	0.05
99	0.15	105	0.03
100	0.20		
		Total	**1.00**

Finished cars are transported across the bay, at the end of each day, by ferry. If the ferry has space for only 101 cars, what will be the average number of cars waiting to be shipped, and what will be the average number of empty space on the boat? Use following Random Numbers to simulate the data provided above - 20, 63, 46, 16, 45, 41, 44, 66, 87, 26, 78, 40, 29, 92, 21.

Q.NO.42. A book store wishes to carry 'Ramayana' in stock. Demand is probabilistic and replenishment of stock takes 2 days (i.e. if an order is placed on March 1, it will be delivered at the end of the day on March 3). The probabilities of demand are given below:

Demand (daily)	0	1	2	3	4
Probability	0.05	0.10	0.30	0.45	0.10

Each time an order is placed, the store incurs an ordering cost of Rs. 10 per order. The store also incurs a carrying cost of Rs. 0.50 per book per day. The inventory carrying cost in calculated on the basis of stock at the end of each day.

The manager of the bookstore wishes to compare two options for his inventory decision.

A. Order 5 books when the inventory at the beginning of the day plus order outstanding is less than 8 books.

B. Order 8 books when the inventory at the beginning of the day plus order outstanding is less than 8.

Currently (beginning 1st day) the store has a stock of 8 books plus 6 books ordered two days ago and expected to arrive next day.

Using Monte-Carlo Simulation for 10 cycles, recommend, which option the manager, should choose.

The two digit random numbers are given below:

89	**34**	**70**	**63**	**61**	**81**	**39**	**16**	**13**	**73**

Q.NO.43. After observing heavy congestion of customers over a period of time in a petrol station, Mr. Petro has decided to set up a petrol pump facility on his own in a nearby site. He has compiled statistics relating to the potential customer arrival pattern and service pattern as given below. He has also decided to evaluate the operations by using the simulation technique.

Arrivals		**Services**	
Inter-arrival time (minutes)	**Probability**	**Service time (minutes)**	**Probability**
2	0.22	4	0.28
4	0.30	6	0.40
6	0.24	8	0.22
8	0.14	10	0.10
10	0.10		

Assume:

(i) The clock starts at 8:00 hours

(ii) Only one pump is set up.

(iii) The following12 Random Numbers are to be used to depict the customer arrival pattern:

78, 26, 94, 08, 46, 63, 18, 35, 59, 12, 97 and 82.

(iv) The following 12 Random Numbers are to be used to depict the service pattern:

44, 21, 73, 96, 63, 35, 57, 31, 84, 24, 05, 37

You are required to find out the

(i) probability of the pump being idle, and

(ii) Average time spent by a customer waiting in queue.

Q.NO.44. A retailer deals in a perishable commodity. The daily demand and supply are variables. The data for the past 500 days show the following demand and supply:

Availability (Kg.)	Supply (No. of days)	Demand (Kg.)	Demand (No. of days)
10	40	10	50
20	50	20	110
30	190	30	200
40	150	40	100
50	70	50	40

The retailer buys the commodity at Rs. 20 per kg. and sells at Rs. 30 per kg. Any commodity remains at the end of the day, has no sales value. Moreover the loss on unsatisfied demand is Rs. 8 per Kg. Given the following pair of random numbers, simulate 6 days sales, demand and profit: (31, 18) (63, 84) (15, 79) (07, 32) (43, 75) (81, 27). The first random number in the pair is that of supply and the second random number is for demand.

Q.NO.45. Using empirical data A process planner is working on plans for producing a new detergent. She wishes to simulate a raw material demand in order to plan for adequate materials – handing and storage facilities. On the basis of usage for a similar product introduced previously, she has developed a frequency distribution of demand in tons per day for a 2-month period. Use this data (shown below) to simulate the raw material usage requirements for 7 periods (days).

Demands, X (tons/ day)	10	11	12	13	14	15	**Total = 60**
Frequency (days)	6	18	15	12	6	3	

Q.NO.46. Empirical data collected on the time required to weld a transformer bracket were recorded to the nearest ¼ minute, as shown in the accompanying table.

Weld Time (min)	Numbers of Observation
< .25	0
.25 < .75	24
.75 < 1.25	42
1.25 < 1.75	72
1.75 < 2.25	38
2.25 < 2.75	14
2.75 < 3.25	10

(a) Formulate a cumulative distribution in percentage terms.

(b) Graphs the frequency and cumulative distributions.

(c) A simulation is to be conducted using random numbers. What simulated weld times (to the nearest .25 minute) would result from the random numbers 25, 90, and 59?

(d) What proportion of the times exceed 2.0 minutes?

Q.NO.47. How simulated times can be used to gain a knowledge of the interface of two assembly activitiesIn an aircraft

assembly operation, activities A precedes activity B, and inventory may accumulate between the two activities.

With the use of random numbers, a simulated sample of performance times yielded the values shown (minutes) in

the accompanying table.

Activity A		Activity B	
Random Number	**Time (min)**	**Random Number**	**Time**
07	.3	63	.5
90	.8	44	.4
02	.2	30	.4
50	.5	98	.9

76	.6	30	.4
47	.5	72	.6
13	.3	58	.5
06	.3	96	.9
79	.7	37	.4

(a) Simulated the assembly of six parts, showing idle time in activity B, waiting time of each part, and number of parts waiting. Note: omit the first random number of A so that activity B begins at time zero.

(b) What was the average length of the waiting line ahead of B (in number of units)?

(c) What was the average output per hour of the assembly line?

Q.NO.48. The Tit-Fit Scientific Laboratories is engaged in producing different types of high class equipment for use in science laboratories. The company has two different assembly lines to produce its most popular product 'Pressure'. The processing time for each of the assembly lines is regarded as a random variable and is described by the following distributions.

Process Time (minutes)	Assembly A1	Assembly A2
10	0.10	0.20
11	0.15	0.40
12	0.40	0.20
13	0.25	0.15
14	0.10	0.05

Using the following random numbers, generate data on the process times for 15 units of the item and compute the expected process time for the product. For the purpose, read the numbers vertically taking the first two digits for the processing time on assembly A1 and the last two digits for processing time on assembly A2.

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

In the first stage, we assign random number intervals to the processing times on each of the assemblies.

Q.NO.49. A businessman is considering taking over a certain new business. Based on past information and his own knowledge of the business, he works out the probability distribution of the monthly costs and sales revenues, as given here:

Cost (in Rs.)	Probability	Sales Revenue (Rs.)	Probability
17000	0.10	19000	0.10
18000	0.10	20000	0.10
19000	0.40	21000	0.20
20000	0.20	22000	0.40
21000	0.20	23000	0.15
		24000	0.05

Use the following sequences of random numbers to be used for estimating costs and revenues. Obtain the probability distribution of the monthly net revenue.

Sequence 1	82	84	28	82	36	92	73	91	63	29
	27	26	92	63	83	02	10	39	10	10
Sequence 2	39	72	38	29	71	83	19	72	92	59
	49	39	72	94	04	92	72	18	09	00

b. Repeat the analysis in (a) by using the following random number streams:

Sequence 1	20	63	46	16	45	41	44	66	87	26
	78	40	29	92	21	36	57	03	28	08
Sequence 2	23	57	99	84	51	29	41	11	66	30
	41	80	62	74	64	26	41	40	97	15

Q.NO.50. Table shows the time remaining (number of days until due date) and the work remaining (number of day's still required to finish the work) for 5 jobs which were assigned the letters A to E as they arrived to the shop. Sequence these jobs by priority rules viz., (a) FCFS, (b) EDD, (c) LS, (d) SPT and (e) LPT.

Job	Number days until due date	Number of day's of work remaining
A	8	7
B	3	4

C	7	5
D	9	2
E	6	6

Q.NO.51. The following jobs have to be shipped a week from now (week has 5 working days)

Job	A	B	C	D	E	F
Number of days of work remaining	2	4	7	6	5	3

Sequence the jobs according to priority established by (a) least slack rule (b) critical ratio rule.

Q.NO.52. In a factory, there are six jobs to perform, each of which should go through two machines A and B, in the order AB. The processing timings (in hours) for the jobs are given here. You are required to determine the sequence for performing the jobs that would minimise the total elapsed time, T. What is the value of T?

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

5. PRODUCTIVITY MANAGEMENT AND QUALITY MANAGEMENT

Q.NO.1. In a particular plant there are 10 workers manufacturing a single product and the output per month consisting of 25 days of that particular product is 200. How much is the monthly productivity?

Q.NO.2. There are two industries A and B manufacturing hose couplings. The standard time per piece is 15 minutes. The output of two small scale industries is 30 and 20 respectively per shift of 8 hours. Find the productivity of each per shift of 8 hours. What is the expected production of each per week consisting of 6 days?

Q.NO.3. The following data is available for a machine in a manufacturing unit:

Hours worked per day	8
Working days per month	25
Number of operators	1
Standard minutes per unit of production	
Machine time	22
Operator time	8
Total time per unit	30

(i) If plant is operated at 75% efficiency, and the operator is working at 100% efficiency, what is the output per month?

(ii) If machine productivity is increased by 10% over the existing level, what will be the output per month?

(iii) If operator efficiency is reduced by 20% over the existing level, what will be the output per month?

Q.NO.4. The following data is available for a manufacturing unit :

No. of operators	:	15
Daily working hours	:	8
No. of days per month	:	25
Std. production per month	:	300 units

Std. Labour hours per unit	:	8

The following information was obtained for November 2015:

Man days lost due to absentism	:	30
Unit produced	:	240
Idle Time	:	276 man hours

Find the following:—

(a) Percent absentism

(b) Efficiency of utilisation of labour

(c) Productive efficiency of labour

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

Q.NO.5. An incentive scheme allows proportionate production bonus beyond 100% performance level. Calculate the amount of (i) Incentive bonus and (ii) Total payment received by an operator on a particular day during which the following particulars apply:

Operation	:	Assembling pocket transistor radio set
Work Content	:	30 Standard minutes per assembled set
Attended Time	:	8 Hours
Time spent on unmeasured work	:	2 Hours
Numbers of sets assembled during the day	:	15

Wage rate : Rs. 4 per hour

(iii) What is the net labour productivity achieved by the operator during the day?

Q.NO.6. Compute the productivity per machine hour with the following data. Also draw your interpretation.

Month	No. of machines employed	Working hours	Production Units
January	400	220	99,000
February	550	180	1,00,000
March	580	220	1,25,000

Q.NO.7. Calculate the standard production per shift of 8 hours duration, with the following data: Observed time per unit = 5 minutes, Rating Factor -120%, Total allowances = 30% of normal time.

Q.NO.8. Study in the Packaging Department of a Softdrinks Manufacturing unit revealed the following facts for a worker Basant Rao Patil.

Cycle No. / Activity Element	1	2	3	4	Performance Rating
(A) Get empty cartoon	0.15 min	0.25 min	—	0.17 min	90%
(B) Place 30 bottles in the cartoon	1.56 min	*	1.80 min	1.75 min	105%
(C) Close the cartoon & set aside	0.20 min	†	0.10 min	0.15 min	95%
(D) Smoking	—	0.50 min	—	—	—

* Bottles slipped out of hands and broke

† Empty cartoon not set aside and used for packaging in the next cycle.

Calculate the standard production by Basant Rao in a shift of 8 hours when the units standard rules allow 10% as Allowance Factor

Q.NO.9. A department works on 8 hours shift, 288 days a year and has the usage data of a machine, as given below:

Product	Annual Demand (units)	Processing time (Standard time in hours)
A	325	5.0
B	450	4.0
C	550	6.0

Calculate (a) Processing time needed in hours to produce products A, B and C, (b) Annual production capacity of one machine in standard hours, and (c) Number of machines required

Q.NO.10. Following results are recorded in a study of work sampling carried for 100 hours in a Machine Shop.

1. Total no. of observations recorded — 2500

2. No. of observations in which no working activity is noticed — 400

3. Ratio of Mannual to Machine elements — 2 : 1

4. Average Rating Factor — 115%

5. No. of articles produced during the study period — 6000

As per the policy of the company, rest and personal allowances are taken as 12% of Normal Time. Calculate Standard Time to produce an article.

Given that the shop produces 42000 articles per month of 25 working days by 5 workers working for a shift of 8 hours per day. Consider absentism to be 7%.

Compute Efficiency of utilisation of Labour and Productive Efficency of Labour.

Q.NO.11. A cement factory in Madhya Pradesh works 7 days a week in 3 shifts per days having maintenance in the first shift of around 2 hours. It has roughly 100 workers which produces only pozzolanic properties cement better known as PPC. The output per month is around 2500 tonnes of PPC. Find the productivity per worker?

Q.NO.12. Compare the productivity of two plant of tobacco company situated in two different state Y and Z in an 8-hour shift. The standard time in manufacture a tobacco packet is 10 min. The output is 40 and 55 of two different plants in a shift. Find also the expected productivity of both plants in a week.

Q.NO.13. For the given data of manufacturing unit which produces spare parts of HEMM the operators time, machine time and total time are 10, 28 and 38 minutes respectively. If there are one operator and working hour per day is 8 hr and considering 22 working days in a month. Find

(a) If plant is working at 65% efficiency, what is the expected output per month?

(b) If plant productivity is increased by 20% over the existing level, what will be the output per month?

(c) If operator efficiency is reduced by 30% due to injury over the existing level, what will be the output per month?

Q.NO.14. Following are the data related to call centre Firm which gives tech and non tech support to large IT companies.

It has 20 executives to address the queries which has 8 hr a shift having on an average 24 working days in month.

On an average the company is able to address around 290 calls in a month.

Additional data for the current month is obtained

(a) No of call logged for the month = 250

(b) Idle time = 275-man hours

(c) Man days lost (absenteeism) = 28.

Find

1. Efficiency of utilisation of manpower
2. Absenteeism (%)
3. Overall productivity of manpower.

Q.NO.15. Find the productivity of IT firm in terms of business achieved for the following data and comment

Quarter	No of Employees	Working Hours	Business Achieved (Rs.)
Q1	1600	800	1000000
Q2	1500	750	1024000
Q3	1700	775	1300000
Q4	2000	900	1200000

Q.NO.16. Find the standard production for 8 hr shift. If allowance = 25% of normal time, Observer time per unit is 7 min and the rating factor is 110%.

Q.NO.17. A captive plant works for one shift in a day i.e. 8 hr a shift for 200 days in a year to cater for large automobile company. It produces three product having annual demand as 425, 429 and 546 units respectively. The processing time (standard time in hr) are 4, 5 and 5.5 hours respectively. Calculate

(a) Processing time required to produce all three products.

(b) Annual production

(c) And number of machine required.

Q.NO.18. Below data are collected related to work study for 150 hrs on a floor shop employing 7 labours having a shift of 8 hrs in a day.

(a) Number of observations documented in total = 3000

(b) Number of observations in which no working activity is observed = 500

(c) Manual to machine ratio = 3:2

(d) Average Rating factor = 120%

(e) Number of product produced during the period of study = 7000

Company has its own policy regarding personal allowance which is pegged at 11% of normal standard time to produce a product.

The floor shop produces 49000 products per month for 24 working days, it has an absenteeism of around 6%.

Calculate efficiency of utilisation of Labour and Productive Efficiency of Labour.

6. PROJECT MANAGEMENT, MONITORING AND CONTROL

Q.NO.1. A project consists of seven activities. Activities P, Q, R run simultaneously. The relationships among the various activities is as follows:

Activity	Immediate Successor
P	S
Q	T
R	U

Activity "V is the last operation of the project and it is also immediate successor to S, T and U. Draw the network of the project.

Q.NO.2. Project with the following data is to be implemented. Draw the network and find the critical path.

Activity	Predecessor	Duration (days)	Cost (Rs. Day)
A	-	2	50
B	-	4	50
C	A	1	40
D	B	2	100
E	A,B	3	100
F	E	2	60

1. What is the minimum duration of the project?
2. Draw a Gantt chart for early start schedule.
3. Determine the peak requirement of money and the day on which it occurs in the above schedule.

Q.NO.3. A project has the following time schedule

Activity	1-2	1-3	1-4	2-5	3-6	3-7	4-6	5-8	6-9	7-8	8-9
Time (months)	2	2	1	4	8	5	3	1	5	4	3

Construct a PERT network and compute

- Critical path and its duration
- Total float for each activity

Also, find the minimum number of cranes the project must have for its activities 2-5, 3-7, 5-8 and 8-9 without delaying the project given that one crane is sufficient to carry out the work involved in each activity if taken care of individually.

Q.NO.4. A project consists of five activities. Activities P and Q run simultaneously. The relationship among the various activities is as follows:

Activity	Immediate Successor
P	R
Q	S

Activity T is the last operation of the project and it is also immediate successor to R and S. Draw the network of the Project.

Q.NO.5. XYZ Auto-manufacturing company has to prepare a design of its latest model of motorcycle. The various activities to be performed to prepare design are as follows:

Activity	Description of activity	Preceding activity
A	Prepare drawing	—
B	Carry out cost analysis	A
C	Carry out financial analysis	A
D	Manufacture tools	C
E	Prepare bill of material	B, C
F	Receive material	D,E
G	Order sub-accessories	E
H	Receive sub-accessories	G
I	Manufacture components	F
J	Final assembly	I,H
K	Testing and shipment	J

Prepare an appropriate network diagram.

Q.NO.6. The following table gives data on normal time & cost and crash time & cost for a project.

Activity	Normal		Crash	
	Time (days)	**Cost (**Rs.**)**	**Time (days)**	**Cost (**Rs.**)**
1—2	6	600	4	1,000
1—3	4	600	2	2,000
2—4	5	500	3	1,500
2—5	3	450	1	650

3—4	6	900	4	2,000
4—6	8	800	4	3,000
5—6	4	400	2	1,000
6—7	3	450	2	800

The indirect cost per day is Rs. 100.

(i) Draw the network and identify the critical path.

(ii) What are the normal project duration and associated cost?

(iii) Crash the relevant activities systematically and determine the optimum project completion time and cost.

Q.NO.7. Draw the network for the following activities and find critical path and total duration of project.

Activity	Duration (months)	Activity	Duration (months)
1-2	2.5	4-5	2.0
2-3	2.5	5-6	3.0
2-4	1.5	6-7	1.5
3-4	1.0	5-7	1.5
3-5	1.0		

Q.NO.8. The following activities must be accomplished in order to complete a construction project:

Activity	A	B	C	D	E	F	G	H	I	J
Time	3	8	4	2	1	7	5	6	8	9
Predecessors	—	—	AB	B	A	C	EF	DF	GH	I

- Construct a network diagram for this project. Find the CP and the duration of the project.
- Assume that you are project manager of the project mentioned above. The project has progressed for 10 weeks and the status is follows:

Activities completed: A, B, E. Other activities have not started as yet.

- If no managerial action is taken at all when will the project get completed?
- What action might you take to get the project back to a schedule that can be completed by the end of week 42?

Q.NO.9. Given is the following information regarding a project:

Activity	A	B	C	D	E	F	G	H	I	J	K	L
Dependence	-	-	-	AB	B	B	FC	B	EH	EH	CDFJ	K
Duration	3	4	2	5	1	3	6	4	4	2	1	5

Draw the Network Diagram and identify the Critical Path and Project Duration.

Q.NO.10. A project with normal duration and cost along with crash duration and cost for each activity is given below:

Activity	**Normal time (Hrs.)**	**Normal cost (Rs.)**	**Crash time (Hrs.)**	**Crash cost (Rs.)**
1-2	5	200	4	300
2-3	5	30	5	30
2-4	9	320	7	480
2-5	12	620	10	710
3-5	6	150	5	200
4-5	0	0	0	0
5-6	8	220	6	310
6-7	6	300	5	370

Overhead cost is Rs. 50 per hour.

Required:

Draw network diagram and identify the critical path.

Q.NO.11. What are the difference between CPM and PERT.

Q.NO.12. Construct a network diagram satisfying the following conditions.

A<D,C; B<E; D<G,F; E,F<H; G,H,C<I

[Hint: X<Y,Z means both Y and Z cannot start until X is complete.]

Q.NO.13. Construct the network diagram from the data given below and find

(a) total duration of the project

(b) Critical Path

(c) EST, EFT, LST, LFT.

(d) Total float of each activity.

Activity	A	B	C	D	E	F	G	H	I	J
Duration	15	15	3	5	8	12	1	14	3	14
Predecessor Activity	-	-	B	A,C	A	B	D	D	F,G	E,H,I

Q.NO.14. For the given data find the expected duration of the project and variance of the project.

Activity	**Optimistic time (to)**	**Most likely Time (tm)**	**Pessimistic time (tp)**
1-2	6	9	12
1-5	4	7	8
2-3	14	17	20
2-4	7	10	13
2-5	3	5	9
3-7	13	18	25
4-6	10	14	16
4-7	12	15	18
5-6	9	11	12
6-7	17	20	25

Illustration 15

A marketing organization is planning a questionnaire survey on behalf of their client to assess market potential of instant foods. The following activities are involved in this project:

Task	**Duration(days)**			
	Precedence	**Optimistic**	**Most(likely)**	**Pessimistic**
A. Design		2	3	4
Questionnaire				
B.Sample design		6	10	20
C.Testing of		2	4	6
Questionnaire				
and refinements				

D.Recruiting				
interviewers	B	2	3	10
E.Training of	D,A	1	1	1
Interviewers				
F.Allocation of	B	4	5	6
Interviewers				
to territories				

Task	**Duration(days)**			
	Precedence	**Optimistic**	**Most(likely)**	**Pessimistic**
G.Conducting	C,E,F	5	12	25
Interviews				
H.Evaluation of results	G	6	10	20

(a) Find the expected duration and variance of each task.

(b) Draw an arrow diagram (network) of the project.

(c) Calculate EST, EFT, LST, LFT & TF

(d) Identify the critical path.

(e) Find the critical path duration of the project.

(f) What percentage of the project will be complete in 44 days?

Activity	**A**	**M**	**B**	**Te**	**Variance**	**EST**	**EFT**	**LST**	**LFT**	**TF**
A	2	3	4	3	1/9	0	3	12	15	12

(g) Find the no of day by which approximately 100% of the project will be completed

Q.NO.15. A management institute plans to organize a conference on use of "Operation Research for decision making". In order to co-ordinate the project, it has decided to use a PERT network. The major activities and time estimates for activity has been compiled as follows:

Sl.No.	**Activity description**	**Time estimate (a-m-b)**	**Activity that must precede**
A	Design conference meeting theme	1-2-3	None

B	Design front cover of conference proceedings	1-2-3	A
C	Design brochure	1-2-3	A
D	Compile list of distinguished speakers	2-4-6	A
E	Finalize brochure and print it	2-5-14	C and D
F	Make travel arrangements for distinguished speakers	. 1-2-3	D
G	Send brochures	1-3-5	E
H	Receive papers for conference	10-12-20	G
I	Edit papers	3-5-7	H
J	Print proceedings	5-10-15	B and I

(a) Draw the network.

(b) Calculate expected time for each activity and variance for each activity.

(c) Calculates EST, EFT, LST, LFT, TF

(d) Identify critical path.

(e) Find the no of day by which approximately 90% of the project will be completed

7. ECONOMICS OF MAINTENANCE AND SPARES MANAGEMENT

Q.NO.1. M/s Nirmala Toolkit Pvt. Ltd. has a workshop comprising of 20 tool machines of similar type. To improve the preventive maintenance plan, the workshop manager collects the data of failure history of the machines as under

Elapsed time after Maintenance attention (in month)	Probability of failure
1	0.20
2	0.15
3	0.15
4	0.15
5	0.15
6	0.20

It costs Rs. 150 to attend a failed machine and rectify the same. Compute the yearly cost of servicing the broken down machines.

Q.NO.2. A Public transport system is experiencing the following number of breakdowns for months over the past 2 years in their new fleet of vehicles:

Number of breakdowns	**0**	**1**	**2**	**3**	**4**
Number of months this occurred	**2**	**8**	**10**	**3**	**1**

Each break down costs the firm an average of Rs. 2,800. For a cost of Rs. 1,500 per month, preventive maintenance can be carried out to limit the breakdowns to an average of one per month. Which policy is suitable for the firm?

Q.NO.3. Indian Electronics, manufactures TV sets and carries out the picture tube testing for 2000 hours. A sample of 100 tubes was put through this quality test during which two tubes failed. If the average usage of TV by the customer is 4 hours/day and if 10,000 TV sets were sold, then in one year how many tubes were expected to fail and what is the mean time between failures for these tubes?

Q.NO.4. M/s XYZ Pvt. Ltd has 50 identical machines in its facilities. The company has the recorded figure for cost of preventive maintenance (Cp) and cost of breakdown maintenance (Cb) as Rs. 20 and Rs. 100 respectively. The company wants to reduce the breakdown occurrence while minimizing Cp. Given is the data on breakdown occurance.

Probabilities of machine breakdown, by month:

Months after servicing that breakdown occurs (i)	Probability that breakdown will occur (Pi)	i.Pi
1	0.10	0.10
2	0.05	0.10
3	0.05	0.15
4	0.10	0.40
5	0.15	0.75
6	0.15	0.90
7	0.20	1.40
8	0.20	1.60
Total	1.00	5.40

Q.NO.5. Compute the requirement of spares for breakdown maintenance for an item that exhibits a Poissonian behavior for failure rates with a mean breakdown rate of five items per month. If the lead time for procuring these spares is one month and a service level of 90 per cent is to be used, what buffer stock of these items should be maintained? (A fixed re-order quantity system of inventory is being used).

Q.NO.6. The main shaft of an equipment has a very high reliability of 0.990. The equipment comes from Russia and has a high downtime cost associated with the failure of this shaft. This is estimated at Rs. 2 crore as the costs of sales lost and other relevant costs. However, this spare is quoted at Rs. 10 lakh at present. Should the shaft spare be procured along with the equipment and kept or not?

Q.NO.7. PQR company has kept records of breakdowns of its machines for 300 days work year as shown below:

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

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

Q.NO.8. A firm is using a machine whose purchase price is Rs. 15,000. The installation charges amount to Rs. 3,500 and the machine has a scrap value of only Rs. 1,500 because the firm has a monopoly of this type of work. The maintenance cost in various years is given in the following table:

Year	1	2	3	4	5	6	7	8	9
Maintenance Cost (Rs.)	260	760	1100	1600	2200	3000	4100	4900	6100

The firm wants to determine after how many years should the machine be replaced on economic considerations, assuming that the machine replacement can be done only at the year end.

Q.NO.9. A large computer installation contains 2,000 components of identical nature which are subject to failure as per probability distribution that follows:

Month End:	**1**	**2**	**3**	**4**	**5**
% Failure to date:	**10**	**25**	**50**	**80**	**100**

Components which fail have to be replaced for efficient functioning of the system. If they are replaced as and when failures occur, the cost of replacement per unit is Rs.3. Alternatively, if all components are replaced in one lot at periodical intervals and individually replace only such failures as occur between group replacement, the cost of component replaced is Rs. 1.

(a) Assess which policy of replacement would be economical.

(b) If group replacement is economical at current costs, then assess at what cost of individual replacement would group replacement be uneconomical.

(c) How high can the cost per unit in-group replacement be to make a preference for individual replacement policy?

Q.NO.10. An electric company which generates and distributes electricity conducted a study on the life of poles. The repatriate life data are given in the following table:

Life data of electric poles

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

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

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

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

Q.NO.11. Product A has a Mean Time Between Failures (MTBF) of 30 hours and has a Mean Time To Repairs (MTTR) of 5 hours. Product B has a MTBF of 40 hours and has a MTTR of 2 hours.

(i) Which product has the higher reliability?

(ii) Which product has greater maintainability?

(iii) Which product has greater availability?

Q.NO.12. Maharashtra Trucking Company (MTC) has a fleet of 50 trucks. The past data on the breakdown of the trucks show the following probability distribution (for a new truck as well as for one which has been repaired after a breakdown).

Months after Maintenance	Probability of Breakdown
1	0.10
2	0.20
3	0.30
4	0.40

Each breakdown costs Rs. 3,000 on an average; which includes cost of time lost and cost of materials and manpower.

The manager of MTC knows the importance of preventive maintenance. He estimates the costs of the preventive maintenance to be Rs. 500 per such preventive action. What should be the appropriate maintenance policy in terms of the mix of preventive and breakdown maintenance

THE END