STRATEGIC COST MANAGEMENT

Time Allowed: 3 Hours **Full Marks: 100**

The figures in the margin on the right side indicate full marks.

SECTION – A (Compulsory)

1) Choose the correct option: **[15 × 2=30]**

(i) The shadow price of skilled labour for SD Ltd. is currently ₹10 per hour. What does this mean?

a) The cost of obtaining additional skilled labour is ₹10 per hour.

b) There is a hidden cost of ₹10 for each hour of skilled labour actively worked.

c) Contribution will be increased by ₹10 per hour for each extra hour of skilled labour that can be obtained.

d) The total costs will be reduced by ₹10 for each additional hour of skilled labour that can be obtained.

(ii) The product of XYZ company is sold at a fixed price of ₹1,500 per unit. As per company's estimate, 500 units of the product are expected to be sold in the coming year. If the value of investments of the company is ₹15 lakhs and it has a target ROI of 15%, the target cost would be:

a) ₹930

b) ₹950

c) ₹1950

d) ₹1050

(iii) Ankit Ltd., operates throughput accounting system. The details of product A per unit are as under:
Selling Price: ₹75
Material Cost: ₹30
Conversion Cost: ₹20
Time to bottleneck resources: 10 minutes.
What is the throughput contribution per bottleneck resource per hour?

a) ₹270

b) ₹150

c) ₹120

d) ₹90

(iv) The break-even point of a manufacturing company is ₹1,60,000. Fixed cost is ₹48,000. Variable cost is ₹12 per unit. The PV ratio will be:

a) 10%

b) 30%

c) 25%

d) 40%

(v) **XYZ Ltd. has the following alternative planned activity levels:**

Total cost (₹)

1,00,000 (Level E)

1,50,000 (Level F)

2,00,000 (Level G)

No. of units produced:

5,000 (Level E)

10,000 (Level F)

15,000 (Level G)

If fixed overhead remains constant, then fixed overhead cost per unit at Level E is:

a) ₹10
b) ₹20
c) ₹25
d) ₹30

(vi) **The Tech Company has fixed costs of ₹400,000 and variable costs are 75% of the selling price. To realize profits of ₹100,000 from sales of 5,00,000 units, the selling price per unit is:**

a) ₹2
b) ₹3
c) ₹4
d) ₹5

(vii) **The Objective Function of a LPP is $Z = 3x_1 + 2x_2$. If $x_1 = 10$ and $x_2 = 5$ then the value of Z is –**

a) 35
b) 40
c) 45
d) 50

(viii) **For a Cost Function $TC = 3Q^2$ 7Q + 12, MC is –**

a) 3Q + 7
b) 6Q
c) 3Q + 14
d) 6Q + 7

(ix) **How long will it take to produce the fifth unit with 85% learning rate, if the third unit took 13 hours?**

a) 10.3 hours
b) 10 hours
c) 11.5 hours
d) 9.73 hours

(x) The Normal duration and Normal cost of an activity are 10 days and ₹350 respectively. The cost slope is ₹75 per day. If the Crash duration is 8 days, then what is the Crash cost of the activity?

a) 400
b) 500
c) 600
d) 650

(xi) Game theory models are classified by the

a) Number of players
b) Sum of all payoffs
c) Number of strategies
d) All of these?

(xii) Four Ps of Total Quality Management:

a) Principles, Project, Problem, & Process
b) People, Process, Problem & Preparation
c) Product identification, Product quality, Product utility & Product expectation
d) None of the above

(xiii) What is the opportunity cost of making a component part in a factory given no alternative use of the capacity?

a) The variable manufacturing cost of the component
b) The total manufacturing cost of the component
c) The total variable cost of the component
d) Zero

(xiv) #Script Ends – is related to which type of programming language?

a) SAS
b) Python
c) SPSS:
d) none of the above

(xv) Which one of the following is not a spreadsheet?

a) Google Sheets
b) MS Excel
c) E-views
d) Quip

Answer:

(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)	(viii)	(ix)	(x)	(xi)	(xii)	(xiii)	(xiv)	(xv)
c	d	a	b	a	c	b	d	c	b	d	b	d	b	c

SECTION – B

Answer any 5 questions out of 7 questions given. Each question carries 14 marks. [5 × 14 = 70]

2) A manufacturing company currently operating at 80% capacity has received an export order from Middle East, which will utilise 40% of the capacity of the factory. The order has to be either taken in full and executed at 10% below the current domestic prices or rejected totally. The current sales and cost data are given below:

Sales	**₹16.00 lakhs**
Direct Material	**₹5.80 lakhs**
Direct Labour	**₹2.40 lakhs**
Variable Overheads	**₹0.60 lakhs**
Fixed Overheads	**₹5.20 lakhs**

The following alternatives are available to the management:

A. Continue with domestic sales and reject the export order.

B. Accept the export order and allow the domestic market to starve to the extent of excess of demand.

C. Increase capacity so as to accept the export order and maintain the domestic demand by:

(i) Purchasing additional plant and increasing 10% capacity and thereby increasing fixed overheads by ₹65,000, and

(ii) Working overtime at one and half time the normal rate to meet balance of the required capacity.

Required: Evaluate each of the above alternatives and suggest the best one. [14]

Answer:

Alternative (A): Continue with domestic sales and reject the export order.

Serial	Description	Workings	₹ Lakhs
1	Capacity	Given – 80%	
2	Sales	Given	16.00
3	Variable Costs	Given	
	Direct Material		5.80
	Direct Labour		2.40
	Variable Overheads		0.60
	Sub Total		8.80
4	Contribution	(2 - 3)	7.20
5	Fixed Costs	Given	5.20
6	Profit	(4 – 5)	2.00

Alternative (B): Accept the export order and allow the domestic market to starve to the extent of excess of demand.

This alternative envisages utilization of 40% of the capacity for the export order and 60% of the capacity for domestic market. Further, the export order is to be executed at 10% below the current domestic prices i.e.., (100-10) % = 90% of the price. Accordingly:

Sales at 100% Capacity = (16 ÷ 80%) = ₹20 Lakhs

Value of the export order = (40% of Capacity × 90% of the Price) = (20 × 40% × 90%) = ₹7.20 lakhs. Value of the domestic sales = (20 × 60%) = ₹12.00 lakhs.

Serial	Description	Workings	₹ Lakhs
1	Capacity	Export 40% + Domestic 60%	
2	Sales	7.20 + 12.00	19.20
3	Variable Costs		
	Direct Material	(5.80 / 80%) × 100%	7.25
	Direct Labour	(2.40 / 80%) × 100%	3.00
	Variable Overheads	(0.60 / 80%) × 100%	0.75
	Sub Total		11.00
4	Contribution	(2 - 3)	8.20
5	Fixed Costs	Given	5.20
6	Profit	(4 – 5)	3.00

Alternative (C): Increase capacity so as to accept the export order and maintain the domestic demand by:

(i) Purchasing additional plant and increasing 10% capacity and thereby increasing fixed overheads by ₹65,000, and

(ii) Working overtime at one and half time the normal rate to meet balance of the required capacity.

Serial	Description	Workings	₹ Lakhs
1	Capacity	Export 40% + Domestic 80%	
2	Sales	7.20 + 16.00	23.20
3	Variable Costs		
	Direct Material	(5.80 / 80%) × 120%	8.70
	Direct Labour	(2.40 / 80%) × 120%	3.60
	Variable Overheads	(0.60 / 80%) × 120%	0.90
	Overtime Premium [Balance capacity of 10%]	(2.40 / 80%) × 10% × 50%	0.15
	Sub Total		13.35
4	Contribution	(2 - 3)	9.85
5	Fixed Costs [Including fixed O/H for capacity increase of 10 %]	(5.20 + 0.65)	5.85
6	Profit	(4 – 5)	4.00

Suggestion: Alternative (C) with the highest profit of ₹4.00 lakhs works out to be the best.

3) (a) A company is organized on decentralized lines, with each manufacturing division operating as a separate profit centre. Each division has full authority to decide on sale of the division's output to outsiders and to other divisions.

Division C has always purchased its requirements of a component from Division A. but when informed that Division A was increasing its selling price to ₹150, the manager of Division C decided to look at outside suppliers. Division C can buy the components from an outside supplier for ₹135.

But Division A refuses to lower its price in view of its need to maintain its return on the investment. The top management has the following information:

C's annual purchase of the component: 1,000 units

A's variable costs per unit: ₹120

A's fixed cost per unit: ₹20

Analyse:

(i) Will the company as a whole benefit, if Division C buys the component at ₹135 from an outside supplier?

(ii) If Division A did not produce the material for Division C, it could use the facilities for other activities resulting in a cash operating savings of ₹18,000. Should Division C then purchase from outside sources?

(iii) Suppose there is no alternative use of Division A's facilities and the market price per unit for the component drops by ₹20. Should Division C now buy from outside. [7]

(b) CELO Company has the capacity of production of 80,000 units and presently sells 20,000 units at ₹100 each. The demand is sensitive to selling price and it has been observed that for every reduction of ₹10 in Selling Price, the demand is doubled.

i) Calculate the Target Cost at full capacity, if Profit Margin on Sale is 25%?

ii) What should be the Cost Reduction Scheme at full capacity if at the present level 40% of the cost is variable and Total Fixed Cost is ₹36 lakhs?

iii) If Rate of Return desired is 16%, Calculate the maximum investment at full capacity. [7]

Answer:

(a) (i) Division C buying the component at ₹135 from an outside supplier

Purchase cost (from outside supplier) (1,000 units × ₹135p.u.)	1,35,000
Less: Saving in variable cost of Division A by reducing division's output (1,000 units × ₹120 p.u.)	1,20,000
Net loss	15,000

Observation: The company as a whole will incur a loss of ₹15,000 if Division C buys the component from an outside supplier at ₹135 p.u.

(ii) Division C buying the component at ₹135 from an outside supplier and Division A saving ₹18,000

Purchase cost (from outside supplier) (1,000 units x ₹135p.u.)	1,35,000
Less: Saving in variable cost of Division A by reducing division's output (1,000 units × ₹120 p.u.)	1,20,000
Operating savings by using facilities for other activities	18,000
Total Savings	1,38,000
Net Gain	3,000

Observation: The company as a whole will benefit by ₹3,000 if Division C buys the component from an outside supplier at ₹135 p.u. and Division A's facilities are used for other activities.

(iii) There is no alternative use of Division A's facilities and the market price per unit for the component drops by ₹20

Purchase cost (from outside supplier) (1,000 units × ₹115 p.u.)	1,15,000
Less: Saving in variable cost of Division A by reducing division's output (1,000 units × ₹120 p.u.)	1,20,000
Net Gain	5,000

Observation: The company as a whole will benefit by ₹5,000 if Division C buys the component from an outside supplier at ₹115 p.u.

(b) (i) **Target Cost at Full Capacity**

Projected Demand

Selling Price (₹ Per Unit)	Demand (Units)	Capacity Utilisation
100	20,000	25%
90	(20,000 × 2) = 40,000	50%
80	(40,000 × 2) = 80,000	100%

Selling Price at Full Capacity = ₹80.00 Target Profit = 25% on Sales = ₹20.00

Target Cost at Full Capacity = (80 – 20) = ₹ 60.00 per unit

(ii) Cost Reduction Scheme

- Computation of Variable Cost per unit At the Present Capacity of 20,000 units Selling Price = ₹100.00 per unit
  Profit Margin = 25% on Sales = ₹25.00 Total Cost = (100 – 25) = ₹75.00
  Variable Cost = 40% of total cost = 40% of 75 = ₹30.00
- Existing Projections of Total Cost at full capacity Total Variable Cost = (₹30 × 80000) = ₹24.00 lakhs Total Fixed Cost = ₹36.00 Lakhs
  Total Cost = (24.00 + 36.00) = ₹60.00 lakhs
- Target Cost = (60 × 80000) = ₹48.00 lakhs
- Cost Reduction Scheme
  Cost Reduction Needed = (Existing Cost – Target Cost) = (60.00 – 48.00) = ₹12.00 lakhs

ii) **Maximum Investment at full capacity**

- Target Profit at full Capacity
  Sales = 80.00 × 80,000 units = ₹64.00 lakhs
  Target Cost = ₹48.00 lakhs
  Target Profit = (64.00 – 48.00) = ₹16.00 lakhs
- Rate of Return on Investment = 16%
- Minimum Investment
  Investment Needed = (Target Profit ÷ Target Return on Investment) = (16.00 ÷ 16%) = ₹100.00 lakhs

4) (a) Production overheads of XYZ Manufacturers Pvt. Ltd. for 500 units of product X are Machine oriented activity cost: ₹1,35,400

Material ordering overheads: ₹69,570
Machine hours are 1.50 hrs per unit and No. of material orders are 6 per unit.
Raw material cost ₹300 per unit and labour cost ₹150 per unit.
Calculate the Total cost of X per Unit? **[7]**

(b) **Quality impacts all aspects of an organization and can result in significant costs. These costs are generally classified into two broad categories: quality control costs and quality failure costs. Discuss the differences between these two categories with examples.** **[7]**

Answer:

(a)

(i) Machine Oriented Cost per Unit

Machine oriented activity cost for 500 units = ₹1,35,400
Machine hours for 500 units = 1.5 × 500 = 750
Machine Oriented Cost per hour = (135400 ÷ 750) = ₹180.53
Machine Oriented Cost per Unit = (180.53 × 1.5) = ₹270.80

(ii) Material Ordering Cost per Unit

Material Ordering Cost = ₹69,570
Material Orders per unit = 6
Material Orders for 500 units = 6 × 500 = 3000
Material Ordering Cost per Order = (69570 ÷ 3000) = ₹23.19
Material Ordering Cost per Unit = (23.19 × 6) = ₹139.14

(iii) Total Cost of X per Unit

Serial	Particulars	(₹)
1	Raw Material cost	300.00
2	Labour cost	150.00
3	Machine Oriented Cost	270.80
4	Material Ordering Cost	139.14
5	Total Cost	859.94

(b) Quality affects all aspects of the organization and has dramatic cost implications. The most obvious consequence occurs when poor quality creates dissatisfied customers and eventually leads to loss of business. However, quality has many other costs, which can be divided into two categories. The first category consists of costs necessary for achieving high quality, which are called quality control costs. These are of two types: prevention costs and appraisal costs. The second category consists of the cost consequences of poor quality, which are called quality failure costs. These include external failure costs and internal failure costs. The first two costs are incurred in the hope of preventing the second two.

Prevention Costs: Prevention costs are all costs incurred in the process of preventing poor quality from occurring. They include quality planning costs, such as the costs of developing and implementing a quality plan. Also included are the costs of product and process design, from collecting customer information to designing processes that achieve conformance to specifications. Employee training in quality measurement is included as part of this cost, as well as the costs of maintaining records of information and data related to quality.

Appraisal Costs: Appraisal costs are incurred in the process of uncovering defects. They include the cost of quality inspections, product testing, and performing audits to make sure that quality standards are being met. Also included in this category are the costs of worker time spent measuring quality and the cost of equipment used for quality appraisal.

Internal Failure Costs: Internal failure costs are associated with discovering poor product quality before the product reaches the customer site. One type of internal failure cost is rework, which is the cost of correcting the defective item. Sometimes the item is so defective that it cannot be corrected and must be thrown away. This is called scrap, and its costs include all the material, labour, and machine cost spent in producing the defective product.

External Failure Costs: External failure costs are incurred when inferior products are delivered to customers. They include cost of handling customer complaints, warranty replacements, repairs of returned products and cost arising from a damaged company reputation.

5. The summarized results of a company for the two years ended 31st December 2023 and 2024 are given below:

Year	2024	2023
Particulars	**₹ lacs**	**₹ lacs**
Sales	**770**	**600**
Direct Materials	**324**	**300**
Direct Wages	**137**	**120**
Variable Overheads	**69**	**60**
Fixed Overheads	**150**	**80**
Profit	**90**	**40**

As a result of re-organisation of production methods and extensive advertisement campaign use, the company was able to secure an increase in the selling prices by 10% during the year 2024 as compared to the previous year. In the year 2023, the company consumed 1,20,000 Kgs. of raw materials and used 24,00,000 hours of direct labour. In the year 2024, the corresponding figures were 1,35,000 kgs of raw materials and 26,00,000 hours of direct labour.

You are required to:

Use information given for the year 2023 as the base year information to analyze the results of the year 2024 and to show in a form suitable to the management the amount each factor has contributed by way of price, usage and volume to the change in profit in 2024. [14]

Answer:

(i) Statement of Variances

Sl. No.	Description	Workings	₹ lacs
1	Sales Variances		
a	Sales price variance	770 – {770 × (100/110)} = 70(F)	70 (F)
b	Sales volume variance	{770 × (100/110)} - 600 = 100(F)	100(F)
c	Sales value variance	770 – 600 = 170(F)	170(F)
d	% of increase in Volume = (100÷600) × 100 = 16.67%		
2	Material Variances		
a	Key computations Material price in 2023 = (30000000)/120000 = ₹250 Material expected to be used in 2024 = (120000/600) × 700 = 140000 Kgs Standard Material Cost for 2024 = 140000 × ₹250 = ₹350 Lacs Material price in 2024 = (32400000)/135000 = ₹240		
b	Material cost variance	350 – 324 = 26 (F)	26(F)
c	Material volume variance	16.67% of Consumption for 2023 = 300×16.67% = 50(A)	50(A)
d	Material usage variance	SP (SQ-AQ) 250(140000-135000) = 12,50,000	12.50(F)
e	Material price variance	AQ(SP-AP) 135000(250-240) = 1350000	13.50(F)
3	Labour Variances		
a	Key computations Labour hours expected to be used in 2024 = (2400000/600) × 700 = 2800000 Labour rate of 2023 = (12000000)/(2400000) = ₹5 per hour Standard labour cost for 2024 = 2800000 × 5 = ₹140 lacs Labour rate of 2024 = (13700000)/(2600000) = ₹5.269 per hour		
b	Labour cost variance	140 -137 = 3 (F)	3(F)
c	Labour volume variance	16.67% of Consumption for 2023 = 120×16.67% = 20(A)	20(A)
d	Labour efficiency variance	SR (SH-AH) 5(2800000-2600000) = 10,00,000	10.00(F)
e	Labour rate variance	AH(SR-AR) 2600000(5 - 5.269) = 6,99,400(A) i.e. say 7 lacs(A)	7.00(A)
4	Variable Overhead Variances		
a	Key computations Standard variable overheads = ₹60 + (₹60 × 16.67%) = ₹70 Standard variable overheads rate per labour hour = ₹60 /24 = ₹2.5 VOH rate of 2024 = (6900000)/(2600000) = ₹2.65 per hour		
b	VOH cost variance	70 - 69 = 1(F)	1(F)
c	VOH volume variance	16.67% of Consumption for 2023 = 60 × 16.67% = 10(A)	10(A)
d	VOH efficiency variance	SR (SH-AH) 2.5(2800000 - 2600000) = 5,00,000	5(F)
e	VOH expenditure variance	AH(SR-AR) 2600000(2.50 – 2.65) = 3,90,000(A) i.e. say 4 lacs(A)	4(A)
5	FOH cost variance	150 – 80 = 70(A)	70(A)

(ii) Reconciliation Statement

(₹ lacs)

Serial	Description	Favourable	Adverse	Rupees
1	Profit for 2023			40.00
2	Variances			
A	Sales			
	Price	70.00		
	Volume	100.00		
	Sub Total	170.00		170.00(F)
1	Profit for 2023			40.00
2	Variances			
B	Material			
	Volume		50.00	
	Usage	12.50		
	Price	13.50		
	Sub Total	26.00	50.00	24.00(A)
C	Labour			
	Volume		20.00	
	Efficiency	10.00		
	Price		7.00	
	Sub Total	10.00	27.00	17.00(A)
D	Variable Overheads			
	Volume		10.00	
	Efficiency	5.00		
	Expenditure		4.00	
	Sub Total	5.00	14.00	
				9.00(A)
E	Fixed Overheads		70.00	70.00(A)
F	Total	211.00	161.00	50.00(F)
3	Profit for 2024			90.00

6. (a) The products of two Plants A and B are to be transported to three Warehouses W_1, W_2 and W_3. The costs (₹'00) of transportation of each unit from Plants to the Warehouses are indicated in the table below. Also provided are the Supply Capacities of the Plants and the Demands of the three Warehouses.

	Warehouse W_1	**Warehouse W_2**	**Warehouse W_3**	**Supply Capacity**
Plant A	**25**	**17**	**25**	**300**
Plant B	**15**	**10**	**18**	**500**
Demand	**300**	**300**	**500**	**1100 \ 800**

Find the Optimum Distribution Schedule and calculate the associated Cost of Transportation. [7]

(b) **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 ₹)	Probability	Sales Revenue (₹)	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 for estimating costs and revenues. Prepare the probability distribution of the monthly net revenue.

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

[7]

Answer:

(a) As per the given data, Total Supply Capacity = 800 units and Total Demand = 1100 units. So the problem is unbalanced. To convert it into a balanced one, a Dummy Plant C having Supply Capacity = 1100 - 800 = 300 units is introduced. Cost of transportation from this plant to any of the warehouses is considered to be 0. The new matrix is shown below.

	Warehouse W_1	Warehouse W_2	Warehouse W_3	Supply Capacity
Plant A	25	17	25	300
Plant B	15	10	18	500
Plant C	0	0	0	300
Demand	300	300	500	1100 \ 1100

Basic Feasible Solution of the problem by VAM is shown in the table below along with the values of Row and Column Numbers (for which calculations are shown below)

Table showing Basic Feasible Solution by VAM (Optimal Solution)

Plants	Warehouse			Supply	Row Penalty			Row Nos. (u_i)
	W_1	W_2	W_3		1	2	3	
A	25	17 100	25 200	200 ~~300~~	8	8	8	$u_1 = 0$ (let)
B	15 300	10 200	18	200 ~~500~~	5	5	8*	$u_2 = -7$
C	0	0	0 300	~~300~~	0	-	-	$u_3 = -25$
Demand	~~300~~	~~100~~ ~~300~~	~~200~~ ~~500~~	1100				
Column Penalty	1 15	10	18*					
	2 10*	7	7					
	3 -	7	7					
Column Nos. (v_j)	$v_1 = 22$	$v_2 = 17$	$v_3 = 25$					

For the Transportation matrix, No. of Rows = m = 3 and No. of Columns = n = 3. So (m + n – 1) = 3 + 3 – 1 = 5. In the above solution No. of Allocated Cells = 5 = m + n – 1

So the solution is Non – degenerate.

Calculation of Row Numbers (u_i) and Column Numbers (v_j) are shown in the table below.

Allocated Cell	Cost (C_{ij})	$C_{ij} = u_i + v_j$	Calculated No.
A - W_2	$C_{12} = 17$	$C_{12} = u_1 + v_2$ Or, $17 = 0 + v_2$	$v_2 = 17$
A – W_3	$C_{13} = 25$	$C_{13} = u_1 + v_3$ Or, $25 = 0 + v_3$	$v_3 = 25$
B – W_2	$C_{22} = 10$	$C_{22} = u_2 + v_2$ Or, $10 = u_2 + 17$	$u_2 = -7$
B – W_1	$C_{21} = 15$	$C_{21} = u_2 + v_1$ Or, $15 = -7 + v_1$	$v_1 = 22$
C – W_3	$C_{33} = 0$	$C_{33} = u_3 + v_3$ Or, $0 = u_3 + 25$	$u_3 = -25$

To test optimality of the solution, Opportunity Costs for each of the Unallocated Cell is computed and shown in the Table below.

Unallocated Cell	Cost (C_{ij})	Row No. (u_i)	Column No.(v_j)	Opportunity Cost (Δ_{ij})
(1)	(2)	(3)	(4)	(5) = (2) – [(3) + (4)]
A – W_1	$C_{11} = 25$	$u_1 = 0$	$v_1 = 22$	3
B – W_3	$C_{23} = 18$	$u_2 = -7$	$v_3 = 25$	0
C – W_1	$C_{31} = 0$	$u_3 = -25$	$v_1 = 22$	3
C – W_2	$C_{32} = 0$	$u_3 = -25$	$v_2 = 17$	8

As no negative Opportunity Cost values are there, the solution is **Optimal.** The Optimum Transportation schedule along with its associated Cost is given below

from Plant	to Warehouse	Transportation cost per unit (₹'00)	Quantity allocated (Units)	Cost (₹'00)
(1)	(2)	(3)	(4)	(5) = (3) × (4)
A	W_2	17	100	1700
A	W_3	25	200	5000
B	W_2	10	200	2000
B	W_1	15	300	4500
C	W_3	0	300	0
TOTAL				13200

So the minimum Total Cost of Transportation = ₹1,320,000
From the above solution it can be concluded that 300 units of Demand of W_3 remains unfulfilled because it is being supplied by C which is a Dummy Plant i.e. non-existent.

(b) Table showing Range of Random Nos. for Cost and Revenue

Cost (₹)	Probability	Cumulative Probability	Random No. Range	Revenue (₹)	Probability	Cumulative Probability	Random No. Range
17000	0.1	0.1	00 - 09	19000	0.1	0.1	00 - 09
18000	0.1	0.2	10 - 19	20000	0.1	0.2	10 - 19
19000	0.4	0.6	20 - 59	21000	0.2	0.4	20 - 39
20000	0.2	0.8	60 - 79	22000	0.4	0.8	40 - 79
21000	0.2	1.0	80 - 99	23000	0.15	0.95	80 - 94
				24000	0.05	1.00	95 - 99

Table showing simulated values of Cost and Sales for the next 20 months

Month	Random No. for Cost	Cost (₹)	Random No. for Sales	Sales (₹)	Monthly Net Revenue (₹)
1	82	21000	39	21000	0
2	84	21000	72	22000	1000
3	28	19000	38	21000	2000
4	82	21000	29	21000	0
5	36	19000	71	22000	3000
6	92	21000	83	23000	2000
7	73	20000	19	20000	0

8	91	21000	72	22000	1000
9	63	20000	92	23000	3000
10	29	19000	59	22000	3000
11	27	19000	49	22000	3000
12	26	19000	39	21000	2000
13	92	21000	72	22000	1000
14	63	20000	94	23000	3000
15	83	21000	04	19000	(2000)
16	02	17000	92	23000	6000
17	10	18000	72	22000	4000
18	39	19000	18	20000	1000
19	10	18000	09	19000	1000
20	10	18000	00	19000	1000

Probability Distribution for Monthly Net Revenue

Net Revenue (₹)	(2000)	0	1000	2000	3000	4000	6000	Total
Probability	1/20	3/20	6/20	3/20	5/20	1/20	1/20	1

7. The following table gives data on normal time & cost and crash time & cost for a project.

Activity	Normal		Crash	
	Time (days)	Cost (₹)	Time (days)	Cost (₹)
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 ₹100.

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

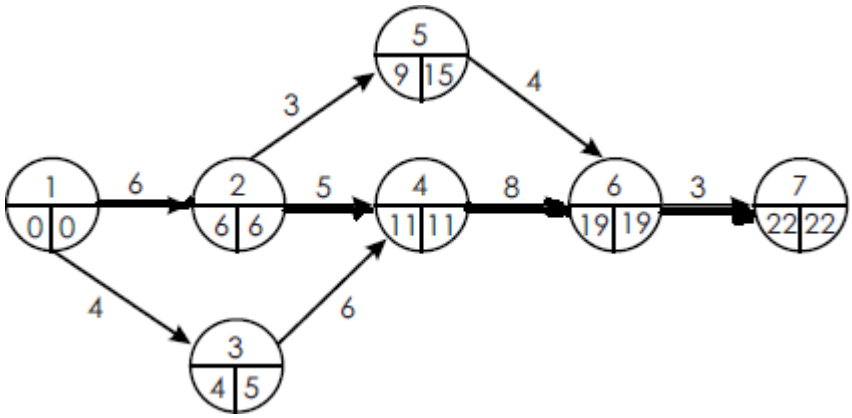
(ii) Calculate the normal project duration and associated cost.

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

[14]

Answers:

The network for normal activity times indicates project duration of 22 days with critical path 1-2-4-6-7. It is shown below

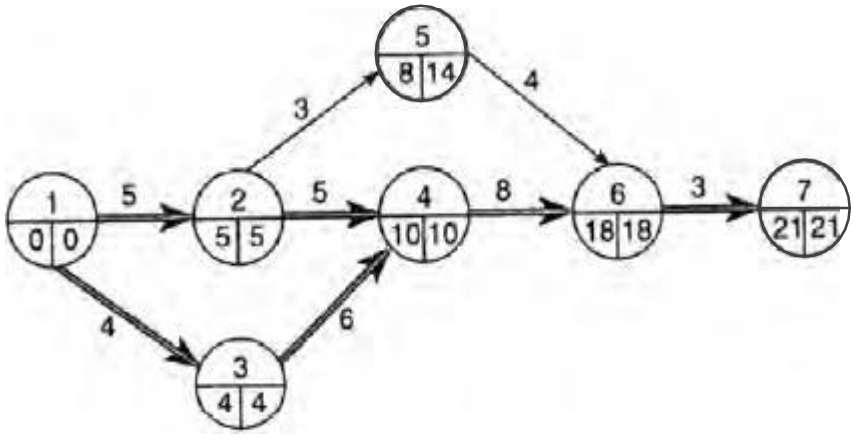


Total Cost associated with it is given as (Normal Direct Cost + Indirect Cost for 22 Days @ ₹100 per Day) Normal Direct Cost = (600 + 600 + 500 + 450 + 900 + 800 + 400 + 450) = ₹4700
Indirect Cost = 22 × 100 = ₹2200
Required Total Cost = 4700 + 2200 = ₹6900

1st Stage of Crashing
Cost slope of each of the Critical Activities of the Network diagram is calculated and ranked as below.

Critical Activity	Cost Slope =	Rank as per ascending order of Cost Slope
1 - 2	(1000 – 600)/ (6 – 4) = ₹200 per day	1
2 – 4	(1500 – 500)/ (5 – 3) = ₹500 per day	3
4 – 6	(3000 – 800)/ (8 – 4) = ₹550 per day	4
6 – 7	(800 – 450)/ (3 – 2) = ₹350 per day	2

As Cost Slope of Activity 1 – 2 is minimum, crashing is to be started from this Activity. Maintaining criticality of the existing Critical Path, Activity 1 – 2 is crashed by 1 Day.



New Network Diagram is shown above. It is having Duration of 21 Days and the associated Total Cost is given as TC = Normal Direct Cost + Indirect Cost (for 21 Days @ ₹100 per Day) + Cost of Crashing Activity 1-2 by 1 Day = 4700 + 21 × 100 + 1 × 200 = ₹7000

It is seen that other activities too have become Critical. Now there are two Critical Paths given by 1 – 2 – 4 – 6 – 7 as well as 1 – 3 – 4 – 6 – 7

2nd Stage of Crashing

Cost Slopes of each of the new Critical Activities are calculated as below.

Cost Slope of Activity 1 – 3 = (2000 – 600)/ (4 – 2) = ₹ 700 per Day & that of 3 – 4 = (2000 – 900)/ (6-4) = ₹550/- per Day.

As there are more than one Critical Path, parallel Crashing is necessary for some of the activities to maintain criticality of the existing Critical Paths. Various options of Crashing and their corresponding Cost Slopes are shown below.

Options	Possible Crash (Days)	Cost Slope (₹/ Day)	Rank
Activities (1 - 2) & (1 - 3)	1*	200 + 700 = 900	4
Activities (1 - 2) & (3 - 4)	1*	200 + 550 = 750	3
Activities (2 - 4) & (1 - 3)	2	500 + 700 = 1200	6
Activities (2 - 4) & (3 - 4)	2	500 + 550 = 1050	5
Activity (4 – 6)	4	550	2
Activity (6 – 7)	1	350	1

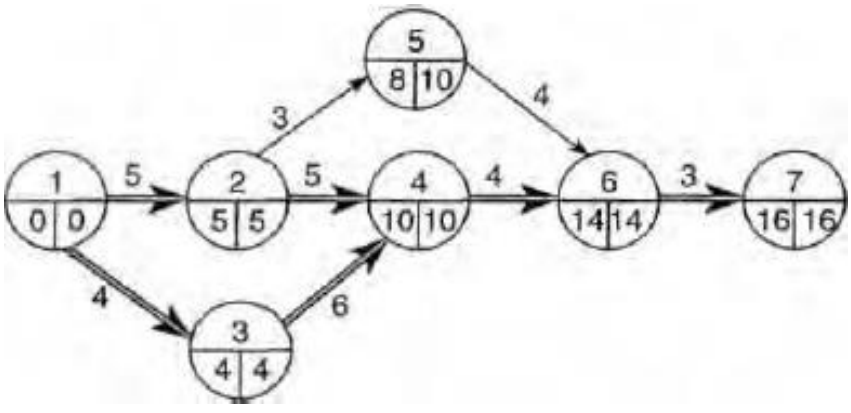
* Though as per the supplied data activities (1-3) & (3-4) can be crashed by 2 days each, but (1 – 2) cannot be crashed more than 1 Day after 1st stage of Crashing.

From the above ranking Crashing of (6-7) by 1 Day is suggested. Due to this project duration will be 20 Days and associated Total Cost = Normal Direct Cost + Indirect Cost for 20 Days @ ₹100 per Day+ Crashing Cost of Activity (1 – 2) by 1 Day @ ₹200 per Day + Crashing Cost of Activity (6 – 7) by 1 Day @ ₹350 per Day = 4700 + 20 × 100 + 1 × 200 + 1 × 350 = ₹7250

3rd Stage of Crashing

After 2nd Stage of Crashing, no new Critical Path emerged. So the options remain same as in the 2nd Stage with the exception of Activity (6 – 7) which is totally crashed in the 2nd Stage.

From the above list of Ranking, Activity (4 – 6) is having lowest Cost Slope. Thus it is crashed by 4 days now. New Network having project duration of 16 Days is shown below.

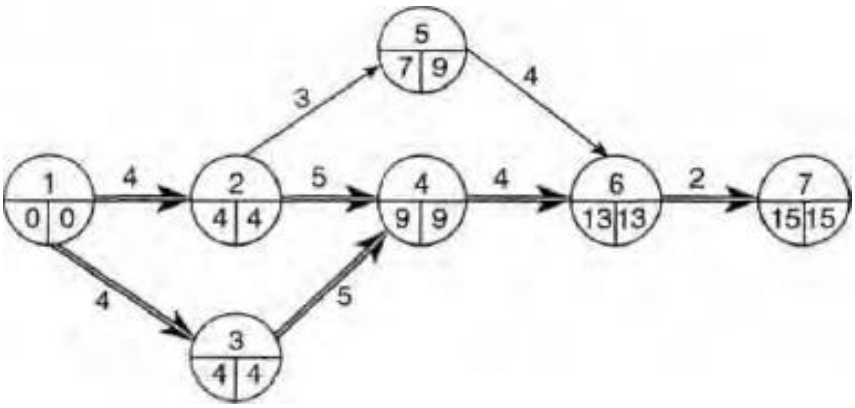


Total Cost of the Project = Normal Direct Cost + Indirect Cost (for 16 Days @ ₹100/ Day) + Crashing Cost [for Activity (1 – 2) by 1 Day @ ₹200/ Day + for Activity (6 – 7) by 1 Day @ ₹350/ Day + for Activity (4 – 6) by 4 Days @ ₹550/ Day] = 4700 + 1600 + 200 + 350 + 550 × 4 = ₹9050

4th Stage of Crashing

After 3rd Stage of Crashing, no new Critical Path emerged. So the options remain same as in the 2nd Stage with the exception of Activities (6 – 7) and (4 – 6) which are fully crashed in the 2nd and 3rd Stages.

From the above list of Ranking, Activity (1 – 2) and (3 – 4) together is having lowest Cost Slope. Thus both are crashed by 1 day now. New Network having project duration of 15 Days is shown below.



Total Cost of the Project

= Normal Direct Cost + Indirect Cost (for 15 Days @ ₹100/ Day) + Crashing Cost [for Activity (1 – 2) by 1 Day @ ₹200/ Day + for Activity (6 – 7) by 1 Day @ ₹350/ Day + for Activity (4 – 6) by 4 Days @ ₹550 per Day + for Activities (1 – 2) & (3 – 4) together by 1 Day @ ₹750/Day]

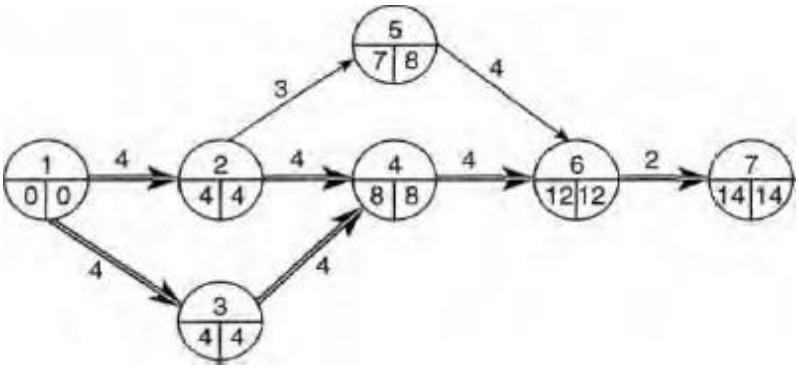
= 4700 + 1500 + 200 + 350 + 550 × 4 + 750 = ₹9700

5th Stage of Crashing

Though after 4th Stage of Crashing no new Critical Paths emerged, but the Activity (1 – 2) has been crashed fully. Thus the options remaining are as follows.

Options	Possible Crash (Days)	Cost Slope (₹/ Day)	Rank
Activities (2 - 4) & (1 - 3)	2	500 + 700 = 1200	2
Activities (2 - 4) & (3 - 4)	1*	500 + 550 = 1050	1

* Though Activity (2 - 4) can be crashed by 2 Days but after 4th Stage, (3 – 4) has only 1 Day of Crashing left. As Cost Slope of Activities (2 – 4) & (3 – 4) taken together is least, both are crashed by 1 Day and the new Network diagram is shown below. It shows project duration of 14 Days.



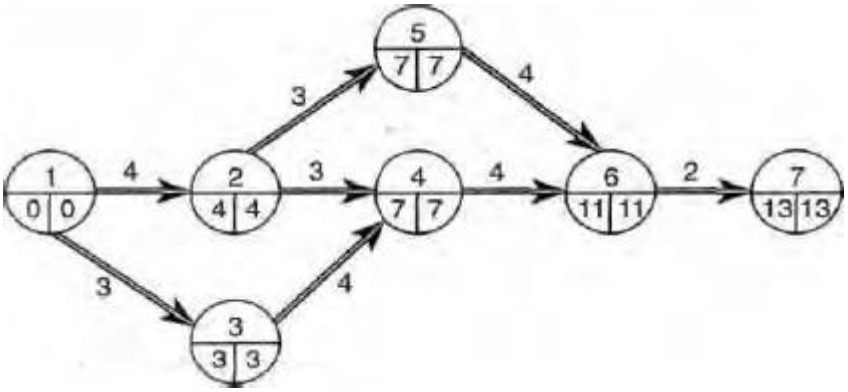
Total Cost of the Project

= Normal Direct Cost + Indirect Cost (for 14 Days @ ₹100/ Day) + Crashing Cost [for Activity (1 – 2) by 1 Day @ ₹200/ Day + for Activity (6 – 7) by 1 Day @ ₹350/ Day + for Activity (4 – 6) by 4 Days @ ₹550/ Day + for Activities (1 – 2) & (3 – 4) together by 1 Day @ ₹750/Day + for Activities (2 – 4) & (3 – 4) together by 1 Day @ ₹1050/ Day]

= 4700 + 1400 + 200 + 350 + 550 × 4 + 750 + 1050 = ₹10650

6th Stage of Crashing

After 5th Stage of Crashing no new Critical Paths emerged. So the available option as per the table above is to crash (2 – 4) and (1 – 3) together and they can be crashed by 1 Day because after 5th Stage only 1 Day of crashing is available for Activity (2 – 4). The new Network diagram having project duration of 13 Days is shown below.



Total Cost of the Project

= Normal Direct Cost + Indirect Cost (for 13 Days @ ₹100/ Day) + Crashing Cost [for Activity (1 – 2) by 1 Day @ ₹200/ Day + for Activity (6 – 7) by 1 Day @ ₹350/ Day + for Activity (4 – 6) by 4 Days @ ₹550 per Day + for Activities (1 – 2) & (3 – 4) together by 1 Day @ ₹750/Day + for Activities (2 – 4) & (3 – 4) together by 1 Day @ ₹1050/ Day + for Activities + for Activities (2 – 4) & (1 – 3) by 1 Day @ ₹1200/ Day]

= 4700 + 1300 + 200 + 350 + 550 × 4 + 750 + 1050 + 1200 = ₹11750

From the diagram it is clear that all the paths of the Network are Critical. Also activities of the path 1 – 2 – 4 – 6-7 are each fully crashed. Thus no further crashing of the Network is possible.

It is noticed that the Total Cost of the Project kept on increasing all along. This has happened due to the fact that the rate of decrease of Indirect Cost is much lower than the rate of increase of Direct Cost for Crashing. Hence optimum duration of the project cannot be obtained and rather minimum possible duration is obtained and that value is 13 Days. Associated Total Cost of project is ₹11950.

8. (a) The Management of a company is negotiating with its Union for revision of hourly wages of its employees. The Management deployed a Consulting Firm who has prepared a payoff matrix for the purpose which indicates the additional hourly cost (in ₹) to the company. It is shown below: you being a part of the Consulting Firm have to assist the Management in selecting the best strategy. Calculate the value of the game? Analyse how is it going to affect the company's cost?

Management's Strategies	Strategies of the Union			
	U1	U2	U3	U4
M1	2.50	2.70	3.50	– 0.20
M2	2.00	1.60	0.80	0.80
M3	1.40	1.20	1.50	1.30
M4	3.00	1.40	1.90	0

[7]

(b) There are two variables that need to be studied – Exports of raw cotton and Imports of manufactured goods into India. Following dataset for 7 years is provided. Suggest what kind of regression model should be used here? What are the results of this regression? Analyse the model estimators.

	₹ in Crores						
Exports	42	44	58	55	89	98	60
Imports	56	49	53	58	67	76	58

[7]

Answer:

(a) As the Management's objective is to minimise the cost, they can be considered as the Minimising Player and the Union as the Maximising Player in this problem of Game. Thus, to solve the problem we have to recast the given Payoff Matrix by transposing it as below: -

Strategies of the Union	Management's Strategies				Row Minimum
	M1	M2	M3	M4	
U1	2.50	2.00	1.40	3.00	1.40 = Maximin
U2	2.70	1.60	1.20	1.40	1.20
U3	3.50	0.80	1.50	1.90	0.80
U4	-0.20	0.80	1.30	0	-0.20
Column Maximum	3.50	2.00	1.50 = Minimax	3.00	

Maximin value (1.40) ≠ Minimax value (1.50). Thus, Saddle Point does not exist. So this is a problem of Mixed Strategy. Since the matrix is not a (2×2) Matrix, Dominance Rules are applied to reduce its size to make it a (2×2) Matrix.

As all the elements of the 3rd Row of the above matrix are either greater than or equal to the corresponding elements of the 4th Row, the 3rd Row can be considered to dominate the 4th. So the 4th Row is ignored and the new matrix is shown below.

Strategies of the Union	Management's Strategies			
	M1	M2	M3	M4
U1	2.50	2.00	1.40	3.00
U2	2.70	1.60	1.20	1.40
U3	3.50	0.80	1.50	1.90

Again all the elements of the 1st Column are greater than the corresponding elements of the 2nd Column, the 1st Column is dominated by the 2nd Column. Hence the 1st Column is ignored and the new matrix is shown below.

Strategies of the Union	Management's Strategies		
	M2	M3	M4
U1	2.00	1.40	3.00
U2	1.60	1.20	1.40
U3	0.80	1.50	1.90

All the elements of the 3rd Column (i.e. for Strategy M_4) of this matrix are more than the corresponding elements of 2nd Column (i.e. for Strategy M_3). Hence M_4 is dominated by M_3 and ignored. The new matrix is shown below.

Strategies of the Union	Management's Strategies	
	M2	M3
U1	2.00	1.40
U2	1.60	1.20
U3	0.80	1.50

Again all the elements of the 1st Row (for strategy U_1) are greater than the corresponding elements of the 2nd Row (for strategy U_2). So U_2 is dominated by U_1 and ignored. The new matrix is shown below.

Strategies of the Union	Management's Strategies	
	M2	M3
U1	2.00	1.40
U3	0.80	1.50

This is a (2 × 2) Matrix. Now the problem of Game is solved by using Odds Method. Odds are calculated as below.

Strategies of the Union	Management's Strategies		ODDs
	M2	M3	
U1	2.00 = a_1	1.40 = a_2	b1 – b2 = 0.80 – 1.50 = 0.70
U3	0.80 = b_1	1.50 = b_2	a1 – a2 = 2.00 – 1.40 = 0.60
ODDs	a2 – b2 = 1.40 – 1.50 = 0.10	a1 – b1 = 2.00 – 0.80 = 1.20	Sum of the ODDs = 1.30

Probabilities of the Union and the Management taking their different strategies are calculated as follows –

P(U1) = (b1 – b2) ÷ [(b1 – b2) + (a1 – a2)] = 0.70 / [0.70 + 0.60] = 0.70/1.30 = 7/13

P(U3) = (a1 – a2) ÷ [(b1 – b2) + (a1 – a2)] = 0.60 / [0.70 + 0.60] = 0.60/1.30 = 6/13

P(M2) = (a2 – b2) ÷ [(a2 – b2) + (a1 – b1)] = 0.10 / [0.10 + 1.20] = 0.10/1.30 = 1/13

P(M3) = (a1 – b1) ÷ [(a2 – b2) + (a1 – b1)] = 1.20 / [0.10 + 1.20] = 1.20/1.30 = 12/13

Value of the Game = v = [a1(b1 – b2) + b1(a1 – a2)] ÷ [(b1 – b2) + (a1 – a2)]

= [2.00×0.70 + 0.80×0.60] ÷ [0.70+ 0.60]

= [1.40 + 0.48] /1.30 = 1.88/1.30 = 1.45

So the Union chooses its Strategies U_1, U_2, U_3 & U_4 with probabilities (7/13, 0, 6/13, 0) and the Management chooses its Strategies M1, M2, M3 & M4 with probabilities (0, 1/13, 12/13, 0).

Expected Gain to the Union is ₹1.45 and the corresponding Loss to the Management is ₹1.45.

Thus, the hourly cost of the company will increase by ₹1.45

(b) As only two variables are involved, Simple Linear Regression or SLR model should be used.

Let the Regression model be y = a + bx where x = Exports and y = Imports

Using the concept of Least Squares the values of a and b can be calculated. For that the Normal Equations are - $\Sigma y = a.N + b.\Sigma x$ (where N = No. of pairs of observations) and $\Sigma xy = a.\Sigma x + b.\Sigma x^2$

Sl. No.	x in ₹ Crores	y in ₹ Crores	x2	xy
1	42	56	1764	2352
2	44	49	1936	2156
3	58	53	3364	3074
4	55	58	3025	3190
5	89	67	7921	5963
6	98	76	9604	7448
7	60	58	3600	3480
Total	446	417	31214	27663

Putting the values of Σy, Σx and N in the 1st Normal Equation we get $417 = a.7 + b.446$ (1)

Similarly putting the values of Σxy, Σx and Σx^2 in the 2nd Normal Equation we get

$27663 = a.446 + b.31214$ (2)

From (1) we get $a = (417 – 446b)/7$

Substituting the above expression for 'a' in (2) we get $27663 = 446(417 – 446b)/7 + 31214b$

Or, $27663 = 26568.86 – 28416.57b + 31214b$

Or, $1094.14 = 2797.43b$ Or, $b = 0.39$

Putting b = 0.39 in the expression for 'a' we have a = (417 – 446×0.39)/7 = 34.72
Substituting the values of a and b in the assumed model we get, y = 34.72 + 0.39x
Thus, the given data can be fit to the SLR Model y = 34.72 + 0.39x
From this, Estimators Slope and y intercept can be interpreted as follows –
Slope = b = 0.39 indicates the amount of change in y (Imports) per unit change in the value of x (Exports)
y intercept = value of y when x = 0 i.e 34.72 indicates that even for no Exports there will be Imports worth 34.72 Crores of Rupees.