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

The figures in the margin on the right side indicate full marks.
Where considered necessary, suitable assumptions may be made and clearly indicated in the answer.

SECTION – A : STRATEGIC COST MANAGEMENT FOR DECISION MAKING

Answer to Question No. 1 & 6 in Section A, are compulsory.

Further, answer **any 3** from Question nos. 2, 3, 4 & 5**.**

1. (a)

Sl. No.	Answer	Justification
(i)	(c)	Blue ocean strategists recognize that market boundaries exist only in managers' minds, and they do not let existing market structures limit their thinking. To them, extra demand is out there, largely untapped. Thus exploiting existing markets [**C**] cannot be an option.
(ii)	(d)	The advantages of cost control are • The advantages of cost control are mainly as follows: • Achieving the expected return on capital employed by maximizing or optimizing profit. • Increasing the productivity of the available resources. • Delivering the product or service to the customers at a reasonable price. • Continued employment and job opportunity for the workers • Economic use of limited resources of production • Increased credit worthiness • Prosperity and economic stability of the industry Thus it is clear that cost control is not a corrective function. Point **D** is the answer
(iii)	(d)	The key focus of the Value Analysis (VA) approach is the management of 'functionality' to yield value for the customer. If a company seeks to reduce the costs of producing a product, then it must seek out costs that are unnecessary or items of the product that provide no functional value to the customer. In this case the first three (No cost can be removed if it compromises the quality of the product or its reliability, marketability is another issue that cannot be compromised and any activity that reduces the maintainability of the product increases the cost of ownership to the customer and can lower the value attached to the product) are issues of adding functionality to

		add value for the customer. Thus Point **D** is the odd answer and all other three are issues of VA.
(iv)	(a)	Value Analysis is a process of improving value for money in a product, service or company. It is a systematic approach to analyze, identify and reduce costs and/or improve performance. The focus of Value Analysis is to optimize value by eliminating or reducing unnecessary costs and improving effectiveness of resources. This is done by examining the functions that are performed, the processes and materials used, the costs associated and the overall performance of the system. *Exchange value is the amount of money that can be exchanged for a given item or service and is not a part of Value Analysis*. Thus **A** is the answer.
(v)	(c)	
(vi)	(b)	Justification 400 Units of Product B should take (× 4 hours) = 1600 hours But did take (active hours) = 1660 hours Efficiency variance in hours = 60 hours × standard rate per hour × 1.70 102 (A)
(vii)	(a)	Budgeted C/S ration = 30% Therefore, Budgeted Contribution = 30% × budgeted selling price = 30% × ₹ 300 = ₹ 90 Sales Volume should have been = 500 units But was = 521 units Sales volume variance in units = 21 units (F) × Standard contribution per unit = × ₹ 90 Sales volume contribution variance = ₹ 1,890 (F)
(viii)	(c)	Weeks worked per year = 52 – 4 = 48 Hours worked per year = 48 × 40 hours = 1920 hours Hours chargeable to clients = 1920 × 90% = 1728 Total expenses = ₹ 10,000 + ₹ 40,000 = ₹ 50,000 Hourly rate = $\frac{50000}{1728}$ = ₹ 28.94

2. (a) Taiichi Ohno (1912-1990) is more a symbol of Japan's manufacturing resurgence after the Second World War. Born in Dalian, in eastern China, he joined Toyota Automatic Loom Works between the wars. Ohno felt that there was no reason other than inefficiency and wastefulness why Toyota's productivity should be any lower than that of Detroit. Hence, he set out to eradicate inefficiency and eliminate waste in that part of the production process that he was responsible for. This became the core of the so-called Toyota Production System (TPS) that he and others subsequently developed between the mid-1940s and the mid-1970s. Several elements of this system have become familiar in the West; for example, muda (the elimination of waste), jidoka (the injection of quality) and kanban (the tags used as part of a system of just-in-time stock control). Lean was evolved from the manufacturing philosophy of the Toyota Production System. The cornerstone of lean is the elimination of waste from processes with a mindset of continuous improvement. In its most basic form, Lean Manufacturing is the systematic elimination of waste by focusing on production costs, product quality and delivery, and worker involvement. It is said that the famed Toyota Production system was inspired by what the Toyota executives learned during their visits to the Ford Motor Company in the 1920s and developed by Toyota leaders such as Taiichi Ohno and consultant Shigeo Shingo after World War II. Broadly speaking, Lean Manufacturing represents a fundamental paradigm shift from traditional "batch and queue" mass production to production systems based on product aligned "single-piece flow, pull production." Whereas "batch and queue" involves mass-production of large inventories of products in advance based on potential or predicted customer demands, a "single-piece flow" system rearranges production activities in a way that processing steps of different types are conducted immediately adjacent to each other in a continuous and single piece flow. If implemented properly, a shift in demand can be accommodated immediately, without the loss of inventory stockpiles associated with traditional batch-and-queue manufacturing.

Lean Accounting is the application of lean thinking to all accounting and finance processes and systems. It is an essential component of a successful lean transformation for any organization. Lean accounting uses a method that categorizes costs by value stream rather than by department. This approach "provides the basis for sound management decisions". The researchers define value stream accounting as "tracking revenue and the associated variable costs required to generate those sales." It is experienced that value stream costing includes a simpler cost collection method and reduces the number of cost centers. They also list features of value stream accounting as:

- Costs calculated weekly

- No distinction made between direct or indirect costs – all costs of the value stream are considered direct costs
- Value stream costs include labour, materials, production support, machines and equipment, operation support, facilities and maintenance
- Value stream costing provides a more accurate picture by elimination of unnecessary costs outside control of value stream managers

Lean accounting groups together costs that fall outside of the value stream as "business sustaining costs" that do not get included in value stream costs. This, in turn, helps the businesses to find better price points for products and do further research into high-cost areas. The bottom line is that Lean accounting can help business leaders quickly know if they are heading in the right direction or need to make a change. Three principles guide Lean Accounting and form the foundation for all of accounting's work and interaction with the organization:

i. Customer value: Delivering the relevant and reliable information in a timely manner to all users of the information inside the organization.

ii. Continuous improvement: Improving accounting processes, cross-functional business processes and the information used inside the business for analysis and decision making.

iii. Respect for people: Adopting a learning attitude by seeking to understand root causes of business problems and issues in a cross-functional, collaborative manner.

(b) TQM is a vision based, customer focused, prevention oriented, Customer Focus Total Employee Commitment Process Approach Integrated System Strategic and Systematic Approach Continual Improvement Fact-based Decision-making Communications Principles of TQM continuous improvement strategy based on scientific approach adopted by cost conscious people committed to satisfy the customers first time every time. It aims at Managing an organization so that it excels in areas important to the customer. Principles of TQM are

- Customer Focus: The first of the Total Quality Management principles puts the focus back on the people buying your product or service. Your customers determine the quality of your product. If your product fulfills a need and lasts as long or longer than expected, customers know that they have spent their money on a quality product. When you understand what your customer wants or needs, you have a better chance of figuring out how to get the right materials, people, and processes in place to meet and exceed their expectations.

- Total Employee Commitment: You can't increase productivity, processes, or sales without the total commitment of all employees. They need to understand the vision and goals that have been communicated. They must be sufficiently trained and given the proper resources to complete tasks in order to be committed to reaching goals on time.
- Process Approach: Adhering to processes is critical in quality management. Processes ensure that the proper steps are taken at the right time to ensure consistency and speed up production.
- Integrated System: Typically, a business has many different departments, each with their own specific functions and purposes. These departments and functions should be interconnected with horizontal processes that should be the focus of Total Quality Management. But sometimes these departments and functions operate in isolated silos. In an integrated system, everybody in every department should have a thorough understanding of policies, standards, objectives, and processes. Integrated systems help the company to look for continual improvement in order to achieve an edge over the competition.
- Strategic and Systematic Approach: The International Organization for Standardization (ISO) describes this principle as: "Identifying, understanding and managing interrelated processes as a system contributes to the organization's effectiveness and efficiency in achieving its objectives." Multiple processes within a development or production cycle are managed as a system of processes in an effort to increase efficiency.
- Continual Improvement: Optimal efficiency and complete customer satisfaction do not happen in a day– your business should continually find ways to improve processes and adapt your products and services as customer needs shift.
- Fact-based Decision-making: Analysis and data gathering lead to better decisions based on the available information. Making informed decisions leads to a better understanding of customers and your market.
- Communications: Everybody in your organization needs to be aware of plans, strategies and methods that will be used to achieve goals. There is a greater risk of failure if you don't have a good communication plan.

The essential requirements for successful implementation are described as the **six C's** of TQM as tabulated below

- **Commitment -** If a TQM culture is to be developed, total commitment must come from top management. It is not sufficient to delegate 'quality' issues to a single person. Quality expectations must be made clear by the top management, together with the support and training required for its achievement.
- **Culture -** Training lies at the centre of effecting a change in culture and attitudes. Negative perceptions must be changed to encourage individual contributions and to make 'quality' a normal part of everyone's job.
- **Continuous Improvement** - TQM should be recognised as a 'continuous process'. It is not a 'one-time programme'. There will always be room for improvement, however small it may be.
- **Co-operation** - TQM visualises Total Employee Involvement (TEI). Employee involvement and cooperation should be sought in the development of improvement strategies and associated performance measures.
- **Customer Focus** - The needs of external customers (in receipt of the final product or service) and also the internal customers (colleagues who receive and supply goods, services or information), should be the prime focus.
- **Control** Documentation, procedures and awareness of current best practice are essential if TQM implementations are to function appropriately. Unless control procedures are in place, improvements cannot be monitored and measured nor deficiencies corrected.

3. (a) (a) Statement of Costs of Quality

		₹
(a)	Inspection or Appraisal Cost (30 x 60,000 shoes)	18,00,000
(b)	Internal failure (re-work) cost (5% x 60,000 × ₹ 18)	54,000
(c)	External failure cost (i.e., transportation + re-work cost) [6% x 60,000 x (₹ 10 + 18)]	1,00,800
(d)	Opportunity cost (i.e., loss of contribution) [5% x (6% x 60,000) x (₹ 600 x 40%)]	43,200
	Total Quality Cost	19,98,000

(b) Profitability Statement

	₹
Sales (60,000 x ₹ 600)	3,60,00,000
Less: Variable Cost (60%)	2,16,00,000
Contribution	1,44,00,000
Less: Quality Cost (as above)	19,98,000
Contribution, net of quality costs	1,24,02,000
Less: Fixed Cost	5,50,000
Net Profit	1,18,52,000

(b) Computation of relevant costs of Material

Material	Relevant Cost	Workings	Amount (₹)
A	Replacement Cost	(1000 × 6)	6,000.00
B	Replacement Cost	(1000 × 5)	5,000.00
C	Realisable Value for 700 units and Replacement Cost for 300 units	[(700 × 2.5) + 300 × 4]	2,950.00
D	Substitution Cost	(300×5)	1,500.00
	Sub Total		15,450.00
	Add: Other expenses		550.00
	Total		16,000.00

As the revenue from the order, is more than the relevant costs of ₹ 16,000 the order should be accepted.

Justification of the solution for each material is given as under

- **Material A**: Since it is not in stock, needs to be purchased from market at replacement cost, hence it is Relevant
- **Material B**: It is in stock and is being regularly used for other production demand. So it needs to be purchased from market at replacement cost, hence it is Relevant
- **Material C**: partly available Ex stock, so realisable value is relevant and balance needs to be purchased from market at replacement cost, hence it is Relevant
- **Material D**: available ex stock but it can be used for other job where replacement cost is 300 units @ ₹ 5 each so 300 × 5 = 1500 is relevant cost

4. **(a)** Division M generates a contribution to profit of ₹ 80 (₹ 850 – ₹ 770) for the group as a whole for every motor sold externally. The incremental cost for every motor which Division S has to buy from outside of the group is ₹ 60 per unit (₹ 800 – [₹ 770 – ₹ 30]). Therefore, from the group's perspective as many external sales as possible should be made before any internal transfers are made. Division M's total capacity is 60000 units so 30000 units should be sold externally and the remaining 30000 units transferred to Division S. From the group's perspective, the cost of supplying these internally is ₹ 60

per unit (₹ 800 – ₹ 740) cheaper than buying externally. Division S's remaining demand of 5000 units should be bought form the external supplier at ₹ 800 per unit. Therefore, the group's current policy will need to be changed. In order to determine the transfer price which should be set for the internal sales of 30000 motors, the perspective of both divisions should be considered. Division M can only sell the motors to Division S and the lowest price it would be prepared to charge is the marginal cost of ₹ 740 of making these units but it will also wish to make a profit on each unit transferred. From Division S's perspective it can buy as many external motors as it needs from between ₹ 740 and ₹ 800. The total group profit will be the same irrespective of where in this range the transfer price is set outside the group at a price of ₹ 800 per unit so this will be the maximum price which it is prepared to pay. Therefore, the transfer price should be set somewhere between ₹ 740 and ₹ 800. The total group profit will be the same irrespective of where in this range the transfer price is set.

(b) Present position on transfer of component @ ₹ 200:

Particulars	Division Alfa	Division Beta
Units Sold	20000	10000
Selling Price/unit	₹ 200	₹ 1,500
Variable Cost/unit	₹ 190	₹ 1,100
Contribution /unit	₹ 10	₹ 400
Fixed Cost/unit	₹ 20	₹ 200
Profit /unit	₹ -10	₹ 200
Total Profit/Loss	₹ -2,00,000	₹ 20,00,000

Overall profit for the Company is ₹18,00,000.

a. Facility of Alfa is rented out and beta buys from market @ ₹210 per unit

Particulars	Division Alfa	Division Beta
Units Sold		10000
Selling Price/unit		₹ 1,500
Variable Cost/unit		₹ 1,120
Contribution /unit		₹ 380
Total Contribution		₹ 38,00,000
Fixed Cost		₹ 20,00,000
Rental Income	₹ 3,00,000	
Total Profit	₹ 3,00,000	₹ 18,00,000

Overall Profit for the Company is ₹ 21,00,000

b. Alfa sells to outside market @ ₹ 220 and Beta buys @ ₹210 per unit from market.

Particulars	Division Alfa	Division Beta
Units Sold	20000	10000
Selling Price/unit	₹ 220	₹ 1,500
Variable Cost/unit	₹ 190	₹ 1,120
Contribution /unit	₹ 30	₹ 380
Total Contribution	₹ 6,00,000	₹ 38,00,000
Fixed Cost	₹ 4,00,000	₹ 20,00,000
Total Profit	₹ 3,00,000	₹ 18,00,000

Overall Profit for the Company is ₹20,00,000

c. Capacity enhancement at the Cost of Capital @ 12 %

Particulars	Division Alfha (Sales)	Division Alfa (transfer)	Division Beta
Units Sold	20000	20000	10000
Selling Price/unit	₹220	₹ 220	₹ 1,500
Variable Cost/unit	₹190	₹ 190	₹ 1,120
Contribution /unit	₹30	₹ 20	₹ 380
Total Contribution	₹ 6,00,000	₹ 4,00,000	₹ 38,00,000
Fixed Cost	₹ 4,00,000	₹ 1,00,000	₹ 20,00,000
Cost of Capital		₹ 1,80,000	
Total Profit	₹2,00,000	₹ 1,20,000	₹ 18,00,000

Overall profit for the Company is ₹ 21,20,000.

Since overall profit is the highest in Option "C", it can be adopted.

5. (a) A. Sales Variance

1. sales price variance = ₹ 770 – (₹770 × 100/110) - ₹600 = ₹ 70 (F)
2. Sales Volume Variance = ₹(770 × 100/110) - ₹ 600 = ₹ 100 (F)

   % increase in volume = (100/600) × 100 = ₹ 16.67%
3. Sales value variance = ₹ 770 - ₹ 600 = ₹ 170 (F)

B. Material Variance

Material price = (300,00,000)/120000 = ₹ 250/-

Material expected to be used = (120000/600) ×700 = 140000kgs

Standard Material Cost = 140000×₹ 250 = ₹ 350 lacs

4. Material Cost variance = ₹(350- 324) = ₹ 26
5. Material volume variance = 300 × 1/6 = ₹ 50 (A)
6. Material usage variance = 5000×₹ 250 = ₹ 12,50,000(F)
7. Material price variance = ₹(250 – 240)×135000 = ₹ 13,50,000 (F)

C. Labour Variance

Labour hours expected to be used = (24,00,000/600) × 700 = 28,00,000

Labour rate = (120,00,000)/24,00,000= ₹ 5

Standard labour cost = 28,00,000 × ₹ 5 = ₹ 140 lacs

8. Labour cost variance = ₹ 140 - ₹ 137 = ₹ 3 (F)
9. Labour volume variance = 120/6 = ₹ 20 (A)
10. Labour efficiency variance = 2 ×₹ 5 = ₹ 10 (F)
11. Labour rate variance = ₹ (20-3-10) = ₹ 7 (A)

D. Overhead Variance

Standard variance overheads = ₹ 60+ (₹ 60 × 16.67 %) = ₹ 70

Standard variable overhead rate per hour = ₹ 60/24 = ₹ 2.5

12. VOH Cost variance = ₹ (70-69) = ₹ 1 (F)
13. VOH volume variance = ₹ 60/6 = ₹ 10 (A)
14. VOH efficiency variance = (2800000- 2600000)× ₹ 2.5 = ₹ 5 (F)
15. VOH expenditure variance = ₹ (10-1-5) = ₹ 4 (A)
16. FOH cost variance = ₹ 70 (A)

Profit Reconciliation Statement:

Particulars	₹ in lakhs	₹ in lakhs
Profit for 2022		40
(+) sales variance :		
Price	70	
Volume	100	
Material Variance :		
Usage	12.50	
Price	13.50	
Labour variance – efficiency	10	
VOH efficiency variance	5	211
		251
(-) material volume variance	50	
Labour Variance :		
Volume	20	
Rate	7	
VOH Variances:		
Volume	10	
Expenditure	4	
FOH cost variance	70	161
Profit for 2023		90

(b) (i) With the benefit of hindsight, the realistic standard should have been ₹ 40. The variance caused by favourable or adverse operating performance should be calculated by comparing actual results against this realistic standard.

	₹
Revised standard cost of actual production (8,000 × ₹ 40)	3,20,000
Actual cost	3,04,000
Total operational variance	16,000 (F)

The variance is favourable because the actual cost was lower than would have been expected using the revised basis. The planning variance reveals the extent to which the original standard was at fault.

		₹
Revised standard cost	8,000 units × ₹ 40 per unit	320,000
Original standard cost	8,000 units × ₹ 25 per unit	200,000
Planning variance		120,000 (A)

It is an adverse variance because the original standard was too optimistic, overestimating the expected profits by understating the standard cost. More simply, it is adverse because the revised cost is much higher than the original cost.

	₹
Planning variance	120,000 (A)
Operational variance	16,000 (F)
Total	104,000 (A)

(ii) If traditional variance analysis had been used, the total cost variance would have been the same, but all the *blame* would appear to lie on actual results and operating inefficiencies (rather than some being due to faulty planning).

	₹
Standard cost of 8000 units × ₹ 25 per unit	2,00,000
Actual cost of 8000 units	3,04,000
Total cost variance	1,04,000 (A)

6. (a) For each of selling price there are three possible outcomes for sales demand, unit variable cost and fixed costs. Consequently, there are 27 possible outcomes. In order to present probability distributions for the two possible selling prices, it would be necessary to compute profits for 54 outcomes. Clearly, there would be insufficient time to perform these calculations within the examination time that can be calculations to be based on an expected value approach.

The expected value calculations are as follows:

(i) Variable cost

	₹
₹(10+₹10×10%)×10/20	5.50
₹ 10×6/20	3.00
₹ (10-10×5%)×4/20	1.90
	10.40

(ii) Fixed cost

	₹
₹ 82,000 × 0.3	24,600
₹ 85,000 × 0.5	42,500
₹ 90,000×0.2	18,000
	85,100

(iii) ₹ 17 selling price

Particulars	Unit
21000 units × 0.2	4,200
19000 units × 0.5	9,500
16500 units × 0.3	4,950
	18,650

(iv) ₹ 18 selling price

Particulars	Unit
19000 units × 0.2	3,800
17500 units × 0.5	8,750
15500 units × 0.3	4,650
	17,200

Expected contribution:

Selling price ₹17 = (₹ 17.00- ₹ 10.40) ×18,650 = ₹ 1,23,090

Selling price ₹ 18 = (₹ 18 - ₹ 10.40) × 17,200 = ₹ 1,30,720

The existing selling price is ₹ 16, and if demand continues at 20,000 units per annum then the total contribution will be 1120 [₹ (16 – 10.40) × 20,000 units]

using the expected value approach, a selling price of ₹ 18 is recommended.

(b) Expected profit = ₹ 1,30,720 - ₹ 85,100 = ₹ 45,620 (fixed cost)

Break Even Point = Fixed cost /Contribution per unit

₹ 85,100/ ₹ 7.60 = 11,197 units

Margin of safety = expected demand (17,200 units) - 11,197 units = 6003 units
% margin of safety = 6003/17,200 = 34.9% of sales
Note that the most pessimistic estimate is above the break - even point.

(c) An Expected Value approach has been used. The answer should draw attention to the limitations of basing the decision solely on expected values. In particular, it should be stressed that risk is ignored and the range of possible outcomes is not considered. The decision ought to be based on a comparison of the probability distributions for the proposed selling prices.

(d) Computer assistance would enable a more complex analysis to be undertaken. In particular, different scenarios could be considered, based on different combinations of assumption regarding variable cost, fixed cost, selling prices and demand. Using computers would also enable the Monte Carlo simulation to be used for more complex decisions.

SECTION – B : QUANTITATIVE TECHNIQUES IN DECISION MAKING

Answer to Question No. 7 & 11 in Section B, are compulsory.
Further, answer **any 2** from Question nos. 8, 9 & 10**.**

7.

Sl. No.	Answer	Justification
(i)	b	6Q + 7 $TC = 3Q^2 + 7Q + 12$ $MC = \frac{dTC}{dQ} = 6Q + 7$
(ii)	d	All the above (Financial analytics can provide business leader a better understanding of business processes and drivers. Value driver analytics, Financial ratio analytics and Predictive Sales Analysis are three types of financial Analytics.

8. (a) First, we convert the equality constraint in terms of two inequalities, one involving '≤' by (-1). Then the primal problem can be written as follows:
Minimize $Z_x = 5x_1 - 6x_2 + 4x_3$
Subject to the constraints
$3x_1 + 4x_2 + 6x_3 \geq 9$
$x_1 + 3x_2 + 2x_3 \geq 5$

$-7x_1 + 2x_2 + x_3 \geq -10$
$X_1 - 2x_2 + 4x_3 \geq 4$
$2x_1 + 5x_2 + 3x_3 \geq 3$
$-2x_1 - 5x_2 + 3x_3 \geq -3$
$x_1, x_2, x_3 \geq 0$

Let y_1, y_2, y_3 y_4, y_5 and y_6 be the dual variables corresponding to the six constraints in given order, then the dual of the given primal problem can be formulated as follows:
Maximize $Z_y = 9y_1 + 5y_2 - 10y_3 + 4y_4 + 3y_5 - 3y_6$
Subject to the constraints
$3y_1 + y_2 - 7y_3 + y_4 + 2y_5 - 2y_6 \leq 5$
$4y_1 + 3y_2 + 2y_3 - 2y_4 + 5y_5 - 5y_6 \leq - 6$
$6y_1 + 2y_2 + y_3 + 4y_4 - 3y_5 + 3y_6 \leq 4$
$y_1, y_2, y_3, y_4, y_5, y_6 \geq 0$

Let $y_7 = y_5 - y_6$, then the above dual problem reduces to the form:
Maximize $Z_y = 9y_1 + 5y_2 - 10y_3 + 4y_4 + 3y_7$
Subject to the constraints
$3y_1 + y_2 - 7y_3 + y_4 + 2y_7 \leq 5$
$-4y_1 - 3y_2 - 2y_3 + 2y_4 - 5y_7 \geq 6$
$6y_1 + 2y_2 + y_3 + 4y_4 - 3y_7 \leq 4$
$y_1, y_3, y_3, y_4 \geq 0$ and y_7 is unrestricted in sign.

(b) Here three plants differ in production cost. Therefore, our problem is to determine the schedule of production which may result in the maximum profit. The various profits per item are as shown in the adjacent table.

Plant	Market	
	X	Y
A	1,900	1,700
B	800	100
C	1,200	500

The profit (selling price - production cost – transportation cost) data from plants to markets are shown below:
from A to X: 4400 – 1500- 1000 = 1900; from A to Y: 4700 – 1500 – 1500 = 1700; From B to X: 4400 – 1600 – 2000 = 800; and so on.

Further, total production at A, B and C plants is 2,000 + 3,000 + 4,000 = 9,000 units while total requirement at X and T is 3,500 + 3,600 = 7,100 units. Hence this is an unbalanced transportation problem. By Introducing a dummy market Z to receive an excess production of 9,000 – 7,100 = 1,900 units, the complete relevant information is summarized in the following table:

Plant	Market			Supply
	X	Y	Dummy	
A	1900 x_{11}	1700 x_{12}	0 x_{13}	2000
B	800 x_{21}	100 x_{22}	0 x_{23}	3000
C	1200 x_{31}	500 x_{32}	0 x_{33}	4000
Demand	3500	3600	1900	9000

Let x_{ij} be quantity to be transported from plant i, (i = 1, 2, 3) to market j, (j = 1, 2, 3). Now the LP model based on the given data can be formulated as follows:

Maximize (total profit) $Z = 1900x_{11} + 1700x_{12} + 800x_{21} + 100x_{22} + 1200x_{31} + 500x_{32}$

Subject to the constraints

$x_{11} + x_{12} + x_{13} = 2,000$
$x_{21} + x_{22} + x_{23} = 3,000$ supply constraints
$x_{31} + x_{32} + x_{33} = 4,000$

$x_{11} + x_{21} + x_{31} = 3,500$
$x_{12} + x_{22} + x_{32} = 7,600$ demand constraints
$x_{13} + x_{23} + x_{33} = 1,900$

$X_{ij} \geq 0$ for all i and j

9. (a) The cumulative probability distributions and random number intervals both for inter arrival time and service time are shown in table below:

Determination of Random Number Internal

No. of arrivals / services / day	Arriving pattern				Servicing pattern			
	Frequency	Probability	Cum. Prob	RN Internal	Frequency	Probability	Cum. Prob	RN Internal
0	4	4/50	0.08	00-07	6	6/50	0.12	00-11
1	8	8/50	0.24	08-23	4	4/50	0.20	12-19
2	20	20/50	0.64	24-63	24	24/50	0.68	20-67
3	10	10/50	0.84	64-83	6	12/50	0.80	68-79
4	6	6/50	0.86	84-95	8	8/50	0.96	80-95
5	2	2/50	1.00	96-99	2	2/50	1.00	96-99

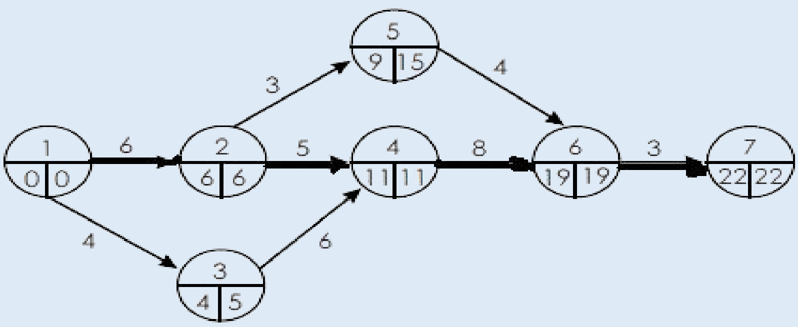
The simulation worksheet developed to the problem is shown in table below:

Simulation Experiments Worksheet

Day	Arrivals		Services		Total no. held from previous day	Total waiting for services	Number services	Held for Next Day
	Random number	Simulated arrival	Random number	Simulated services				
1	09	01	49	02	00	01	02	-
2	54	02	16	01	00	02	01	01
3	42	02	36	02	01	03	02	01
4	01	00	76	03	01	01	03	-
5	80	03	68	03	00	03	03	-
6	06	00	91	04	00	00	04	00
7	06	00	97	05	00	00	05	00
8	26	02	85	04	00	02	04	-
9	57	03	56	02	00	03	02	01
10	79	03	84	04	04	04	04	-

Average number of automobiles remaining in service for more than one day = 3/10.

(b) 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 = (600 + 600 + 500 + 450 + 900 + 800 + 400 + 450) = ₹4,700

10. (a) Let the best fit Linear Trend line to the given data be y = a + bx
(origin at the middle of the year 2014 & 2015 and x unit = 6 months)

Normal equation are Σy = a.n + b.Σx …………….. (1) where n = No, of years = 10 (here)
Σxy = a.Σx + b.Σx^2 ………… (2)
Using the values (from calculations below) of Σy, Σx and n is equation (1) we get,
192 = a.10 + b.0
Or, a = 19.2

Also using the values (from calculations below) of Σxy, Σx and Σx2 and putting in the equation (2) we get,
177 = a.0 + b.330
Or, b = 0.536

Calculations for fitting Straight Line Trend

Year	Sales (y in ₹ Millions)	x	x_2	xy
2010	15.3	-9	81	-137.7
2011	14.6	-7	49	-102.2
2012	16.8	-5	25	-84
2013	17.3	-3	9	-51.9
2014	17.2	-1	1	-17.2
2015	20.9	1	1	20.9
2016	22.3	3	9	66.9
2017	20	5	25	100
2018	23.1	7	49	161.7
2019	24.5	9	81	220.5
Total	192	0	330	177

So the required equation of Straight Line Trend is y = 19.2 + 0.536x
(Origin = At the middle of 2014 & 2015, x unit = 6 months)

For the year 2025, x = 21. So the **estimated sales for the year 2025 = 19.2 + 0.536 × 21 = 30.456 Million ₹**
Yearly rate of increase in Sales = b = 0.536. so **monthly rate of increase in Sales = b/12 = 0.0467 Million ₹**

(b) Profit function is given as: $\prod = 100x - x^2 - 2xy + 200y - 3y^2$

Differentiating the function partially with respect to x we get,

$\prod_x = 100 - 2x - 2y$ -------- (I)

Also differentiating the function partially with respect to y we get

$\prod_y = -2x + 200 - 6y$ -------- (II)

To determine the Critical Point, we have $\prod_x = 0$ and $\prod_y = 0$

So, $100 - 2x - 2y = 0$ Or. $x + y = 50$ ---(1) and $-2x + 200 - 6y = 0$ or, $x + 3y = 100$ ---- (2)

(2) – (1) gives, $2y = 50$ or, $y = 25$

Putting $y = 25$ in (1) we get $x = 25$

Thus Critical Point is (25, 25)

To check whether this point is a local Maxima, we have to find out the values of the 2nd Order Partial Derivatives at this point.

Again differentiating (I) partially with respect to x we get $\prod_{xx} = -2$ Or, $A = -2$ (Let) Or, $A<0$

Similarly differentiating (II) partially with respect to y we get $\prod_{yy} = -6$ Or, $C = -6$ (Let) or, $C<0$

Also differentiating (I) partially with respect to y we get $\prod_{xy} = -2$ Or, $B = -2$ (Let)

So $D = AC - B^2 = (-2) \times (-6) - (2)^2 = 8 > 0$

Hence $D> 0$ and $A, C < 0$

Thus there is a local Maxima at the already determined Critical Point (25, 25)

Required Profit maximizing quantities of the products are x = 25 units and y = 25 units.

Also Maximum profit = Value of the function $\prod$ at $x = 25$ & $y = 25 = 100 \times 25 - 25^2 - 2 \times 25 \times 25 + 200 \times 25 - 3 \times 25^2$

= ₹3,750 (₹000)

11. (1) The described information refers to the LEARNING phenomenon of human beings. The data provided show a continuous reduction of Operating time for both types of surgeries. In other words, there is a continuous improvement in the performance of a human being (the Surgeon) with repetition of the task. This happens only due the Learning effect.

(2) To understand the grasping rate of the surgeon for any type of surgery one has to find out his LEARNING PERCENTAGE for that type of surgery from the supplied data. Higher is the numerical value of the Learning Percentage for a particular type, faster is said to be the grasping rate for that.

(3) If T_N be the Average time required to complete the nth operation and T_1 be that of the first one then the relation between T_N and N (the number of operations done) is given as follows -

$T_N = T_1.N^b$ where b = Learning Index = log (Learning Percentage/100) ÷ log 2

Thus an Exponential relation exists between the Average time required to complete an operation and the number of operations done by the surgeon.

(4) From the basic concept of Learning we can say –

Time required to complete the Nth operation (t_N) = Difference between the total time required for N operations and (N -1) operations

Now total time required for N operations = $N.T_N$ where T_N represents the Average time per operation when N operations are done.

Thus $t_N = N.T_N – (N -1).T_{(N-1)}$

So for the Unilateral type, $t_{59} = 59.T_{59} – 58.T_{58}$ where the values of T_{59} and T_{58} are to be computed from the supplied data for Unilateral type.

Similarly for Bilateral type, $t_{27} = 27.T_{27} – 26.T_{26}$