Chapter 5

Transportation Problems

Learning Objectives :

After learning this chapter you will understand :

- **Transportation Problems.**
- **Formation of a Transportation Problem.**
- **Finding a Basic Feasible Solution by**
  - ✓ **North West Corner Method.**
  - ✓ **Least Cost Method.**
  - ✓ **Vogel's Approximation Method.**
- **Finding Optimal Solution.**
- **Unbalanced Transportation Problems.**
- **Maximisation Transportation Problems.**

Basic Concepts

1. **Transportation Problem :** The transportation problem is one of the sub-classes of linear programming problems in which the objective is to transport various quantities of a single homogenous commodity, that are initially stored at various origins to different destinations in such a way that the total transportation cost is minimum. To achieve this objective we must know the amount and location of available supplies and the quantities demanded in addition to the involvement of cost associated with each sending.

2. **Mathematical Formulation of Transportation Problem :** As a linear programming technique the mathematical formulation of transportation problem is as follows :
The objective function of the transportation problem is

Minimize (total cost) $Z = \sum_{i=1}^{m}\sum_{j=1}^{n} C_{ij} X_{ij}$

Subject to the constraints
$\sum_{j=1}^{n} X_{ij} = a_i, i = 1,2,3,......m$ (supply constraint)
$\sum_{i=1}^{m} X_{ij} = b_j, j = 1,2,3,......m$ (demand constraint)
$X_{ij} \geq 0$, for all i, j
where, m = number of origin points to supply,
n = number of destination points to receive.
C_{ij} is the per unit transportation cost from i^{th} source to j^{th} destination.
For easy presentation and solution, a transportation problem data is generally presented as following table :

To→ From↓	D_1	D_2	………	D_n	Supply a_i
S_1	C_{11} X_{11}	C_{12} X_{12}	………	C_{1n} X_{1n}	a_1
S_2	C_{21} X_{21}	C_{22} X_{22}	………	C_{2n} X_{2n}	a_2
. . .	. . .	. . .		. . .	. . .
S_m	C_{m1} X_{m1}	C_{m2} X_{m2}	………	C_{mn} X_{mn}	a_m
Demand b_j	b_1	b_2	………	b_n	$\sum_{i=1}^{m} a_i = \sum_{j=1}^{n} b_j$

3. **Basic Feasible Solution :** A set of non-negative values $X_{ij}, i = 1,2,....m$ and $j = 1,2,....n$ that satisfies the constraints and contains not more than (m + n – 1) allocations is called a *basic feasible solution* to the transportation problem.
4. **Balanced and Unbalanced Transportation Problems :** A transportation problem is balanced if total supply from all the sources equals total demand in all the destinations, if it is not then the transportation problem is unbalanced.
5. **Steps Required for Solution of a Transportation Problem :**
   - (i) **Formulation of Transportation Problem :** The formulation of transportation problem is similar to the LPP formulation. Here, the objective function is the total transportation cost and the constraints are the supply and demand available at each source and destination respectively.
   - (ii) **Finding a Basic Feasible Solution :** The basic feasible solution can be obtained by several methods, but the most commonly used methods are :
     - (a) North-West Corner Method,
     - (b) Least Cost Method, and
     - (c) Vogel's Approximation Method (VAM or Penalty Method).
   - (iii) **Testing the Initial Solution for Optimality :** The optimality of the solution (i.e., minimum transportation cost) may be tested by any of the two methods viz., Modified Distribution (MODI) and Stepping Stone Method.
   - (iv) **Updating The Solution :** If the solution is not optimal, then a new and better feasible solution is obtained. It is done by transferring units from an occupied cell to an empty cell that has the largest opportunity cost and then shifting the units from other related cells so that the rim conditions are satisfied.
6. **North-West Corner Method :** It follows a systematic and logical approach for setting up the initial solution. The major advantage of the north-west corner rule is that it is very simple and easy to apply and its major disadvantage, however, is the it is not sensitive to costs and consequently yields poor initial solutions, which have very high transportation costs.
7. **Steps Required for finding a Basic Feasible Solution by North-West Corner Rule :**
   - (i) Starting with the cell at the upper left (North-West) corner of the matrix, allocate as much as possible so that either the capacity of the first row is exhausted or the destination demand of the first column is fulfilled, *i.e.*, X_{11} = min (a_1, b_1).
   - (ii) If $b_1 > a_1$, move down vertically to the second row and make the second allocation of magnitude X_{21} = min (a_2, $b_1 - X_{11}$) in cell (2, 1).

     If $b_1 < a_1$, move right horizontally to the second column and make the second allocation of magnitude X_{12} = min ($a_1 - X_{11}$, b_2) in cell (1, 2).

     If $b_1 = a_1$, make the second allocation of magnitude X_{12} = 0 in the cell (1, 2) or X_{21} = 0 in the cell (2, 1).

(iii) Repeat Steps (i) and (ii) moving down towards the lower right corner of the table until all the requirements are satisfied.

Exercise 1

Q1. A company with factories at F_1, F_2 and F_3 supplies to warehouses at W_1, W_2 and W_3. Factories capacities and weekly warehouses requirements are given as under :

Warehouses→ Factories↓	W_1	W_2	W_3	Supply
F_1	16	20	12	200
F_2	14	8	18	160
F_3	26	24	16	90
Demand	180	120	150	450

To minimise shipping costs, determine an initial basic feasible solution to above transportation problem using north west corner method.

Q2. Obtain an initial basic feasible solution to the given transportation problem by North-West Corner Rule :

Demand→ Origin↓	D_1	D_2	D_3	D_4	Supply
O_1	2	3	11	7	6
O_2	1	0	6	1	1
O_3	5	8	15	9	10
Demand	7	5	3	2	17

Q3. Obtain an initial basic feasible solution to the given transportation problem by North-West Corner Rule :

Demand→ Origin↓	D_1	D_2	D_3	D_4	Supply
O_1	4	3	2	5	6
O_2	6	1	4	3	9
O_3	7	2	4	6	7
Demand	4	6	6	6	22

Q4. A company has 3 plants and 4 sales outlets. Data of daily demand at various sales outlets and supply from various plants along with transportation cost per unit between plants and sales outlets are given as under :

Plants	Sales outlets				Supply
	P	Q	R	S	
A	10	2	20	11	15
B	12	7	9	20	25
C	4	14	16	18	10
Demand	5	15	15	15	50

Determine the initial basic feasible solution by North-West Corner Method. Also find the total transportation cost.

Q5. Find initial feasible solution of the following transportation problem by North-west Corner Rule :

To→ From↓	P	Q	R	T	Supply
A	4	6	8	13	50
B	13	11	10	8	70
C	14	4	10	13	30
D	9	11	13	8	50
Demand	40	35	105	20	200

Answers of Exercise 1

1. $F_1 \to W_1$ 180units, $F_1 \to W_2$ 20units, $F_2 \to W_2$ 100units, $F_2 \to W_3$ 60units, $F_3 \to W_3$ 90units, Total Cost Rs. 6600,

2. $O_1 \to D_1$ 6 units, $O_2 \to D_1$ 1 units, $O_3 \to D_2$ 5 units, $O_3 \to D_3$ 3 units, $O_3 \to D_4$ 2 units, Total Cost Rs. 116,

3. $O_1 \to D_1$ 4 units, $O_1 \to D_2$ 2 units, $O_2 \to D_2$ 4 units, $O_2 \to D_3$ 5 units, $O_3 \to D_3$ 1 units, $O_3 \to D_4$ 6 units, Total Cost Rs. 86,

4. A→P 5units, A→Q 10units, B→Q 5units, B→R 15units, B→S 5 units, C→S 10units, Total Cost Rs. 520

5. A→P 40units, A→Q 10units, B→Q 25units, B→R 45units, C→R 30 units, D→R 30 units, D→T 20units, Total Cost Rs. 1795

Basic Concepts

1. **Least Cost Method :** In this method allocations are made to the cells having the minimum transportation cost. The major advantage of least cost method is that the cost associated with each route is considered and allocation is made on the basis of economic desirability. Hence it is observed that in many cases, this method leads to a better allocation than NWCR.
2. **Steps Required for Finding a Basic Feasible Solution by Least Cost Method :**
   (i) The least cost method starts by making the first allocation to that cell whose shipping cost per unit is minimum. In case there is a tie for the lowest cost cell during allocation, any of the lowest cost cells can be selected.
   (ii) The lowest cost cell, selected in first step, is filled as much as possible in view of the plant capacity of its row and the market requirements of its column. If the row capacity of the selected cell is less than the demand of its column cross the entire row of the cell, otherwise cross its entire column.
   (iii) Again select the next lowest cost cell and make an allocation in view of the remaining capacity and requirement of its row and column.
   (iv) The above procedure is repeated till all rim requirements are satisfied.

Exercise 2

Q1. Obtain an initial basic feasible solution to the given transportation problem by Least Cost Method :

Demand→ Origin↓	D_1	D_2	D_3	D_4	Supply
O_1	2	3	11	7	6
O_2	1	0	6	1	1
O_3	5	8	15	9	10
Demand	7	5	3	2	17

Q2. Obtain an initial basic feasible solution to the given transportation problem by Least Cost Method :

To→ From↓	D_1	D_2	D_3	Supply
O_1	12	19	16	14
O_2	19	13	22	16
O_3	8	28	14	12
Demand	17	15	10	42

Q3. Obtain an initial basic feasible solution to the given transportation problem by Least Cost Method :

To→ From↓	D_1	D_2	D_3	D_4	Capacity
F_1	19	30	50	10	7
F_2	70	30	40	60	9
F_3	40	8	70	20	18
Demand	5	8	7	14	34

Q4. A company has 3 plants and 4 sales outlets. Data of daily demand at various sales outlets and supply from various plants along with transportation cost per unit between plants and sales outlets are given as under :

Plants	Sales outlets				Supply
	P	Q	R	S	
A	10	2	20	11	15
B	12	7	9	20	25
C	4	14	16	18	10
Demand	5	15	15	15	50

Determine the initial basic feasible solution by Least Cost Method. Also find the total transportation cost.

Answers of Exercise 2

1. $O_1 \rightarrow D_1$ 6 units, $O_2 \rightarrow D_2$ 1 units, $O_3 \rightarrow D_1$ 1 units, $O_3 \rightarrow D_2$ 4 units, $O_3 \rightarrow D_3$ 3 units, $O_3 \rightarrow D_4$ 2 units, Total Cost Rs. 112,

2. $O_3 \rightarrow D_1$ 12 units, $O_1 \rightarrow D_1$ 5 units, $O_2 \rightarrow D_2$ 15 units, $O_1 \rightarrow D_3$ 9 units, $O_2 \rightarrow D_3$ 1 units, Total Cost Rs. 517,

3. $F_1 \rightarrow D_4$ 7 units, $F_2 \rightarrow D_1$ 2 units, $F_2 \rightarrow D_3$ 7 units, $F_3 \rightarrow D_1$ 3 units, $F_3 \rightarrow D_2$ 8 units, $F_3 \rightarrow D_4$ 7 units, Total Cost Rs. 814,

4. $A \rightarrow Q$ 15units, $B \rightarrow R$ 15units, $B \rightarrow S$ 10units, $C \rightarrow P$ 5units, $C \rightarrow S$ 5units, Total Cost Rs. 475

Basic Concepts

1. **Vogel's Approximation Method :** Vogel's approximation (penalty or regret) method is a heuristic method and is preferred to the other to previous methods. In this method, each allocation is made on the basis of the opportunity cost or penalty that would have incurred if allocations in certain cells with minimum transportation cost were missed. In this method allocations are made so that the penalty cost is minimised. The advantage of this method is that it gives an initial solution which is nearer to optimal solution or is the optimal solution itself.

2. **Steps Required for Finding a Basic Feasible Solution by Vogel's Approximation Method :**
   (i) In each row and column, calculate *penalty* by taking differences between minimum and next to minimum transportation cost. Row penalties are placed on the right hand side of the last column and column penalties are placed on the bottom row.
   (ii) Circle the largest column *penalty* or row *penalty*, if both are equal either of them can be selected.
   (iii) Find the cell with least cost in the circled row or column and allocate as much as possible in that cell in view of the plant capacity of its row and the market requirements of its column. If the row capacity of the selected cell is less than the demand of its column cross the entire row of the cell, otherwise cross its entire column.
   (iv) Revise the penalties again and proceed to step (ii).
   (v) Carry on the procedure until all rows and columns have been crossed out, i.e., distribution is complete.

Exercise 3

Q1. Obtain an initial basic feasible solution to the given transportation problem by Vogel's Approximation Method :

To→ From↓	D_1	D_2	D_3	Capacity
F_1	10	7	8	45
F_2	15	12	9	15
F_3	7	8	12	40
Demand	25	55	20	100

Q2. A company has 3 plants and 4 sales outlets. Data of daily demand at various sales outlets and supply from various plants along with transportation cost per unit between plants and sales outlets are given as under :

Plants	Sales outlets				Supply
	P	Q	R	S	
A	10	2	20	11	15
B	12	7	9	20	25
C	4	14	16	18	10
Demand	5	15	15	15	50

Determine the initial basic feasible solution by Vogel's Approximation Method. Also find the total transportation cost.

Q3. Obtain an initial basic feasible solution to the given transportation problem by Vogel's Approximation Method :

To→ From↓	D_1	D_2	D_3	D_4	Capacity
F_1	19	30	50	10	7
F_2	70	30	40	60	9
F_3	40	8	70	20	18
Demand	5	8	7	14	34

Q4. "Transportation is a special type of Linear Programming Problem". Comment. Find initial feasible solution of the following transportation problem by "Vogel's Approximation Method".

To→ From↓	P	Q	R	S	Supply
X	4	6	22	14	12
Y	2	0	12	2	2
Z	10	16	30	18	20
Demand	14	10	6	4	34

Answers of Exercise 3

1. $F_3 \to D_1$ 25 units, $F_3 \to D_2$ 15 units, $F_1 \to D_2$ 40 units, $F_1 \to D_3$ 5 units, $F_2 \to D_3$ 15 units, Total Cost Rs. 750,

2. A→Q 15units, B→R 15units, B→S 10units, C→P 5units, C→S 5units, Total Cost Rs. 475,

3. $F_2 \to D_1$ 5 units, $F_3 \to D_2$ 8 units, $F_2 \to D_3$ 7 units, $F_1 \to D_4$ 2 units, $F_2 \to D_4$ 2 units, $F_3 \to D_4$ 10 units, Total Cost Rs. 779,

4. X→P 2 units, X→Q 10 units, Y→S 2 units, Z→P 12 units, Z→R 6 units, Z→S 2 units, Total Cost Rs. 408

Basic Concepts

1. **Test For Optimality :** Test procedure for optimality involves examination of each vacant cell to find whether or not making an allocation in it reduces the total transportation cost. Two methods are used for this purpose :
   (i) Stepping Stone Method,
   (ii) Modified Distribution (or MODI) Method.
2. **Steps Required to Find the Optimal Solution by MODI Method :**
   (i) **Finding Basic Feasible Solution :** Determine an initial basic feasible solution consisting m + n – 1 allocations in independent positions using any of the three methods discussed earlier.
   (ii) **Finding Set of Numbers for Rows and Columns :** Determine a set of numbers u_i for each row and v_j for each column using $c_{ij} = u_i + v_j$. To begin assume any one of u_i as zero, generally, that u_i is taken as zero whose row has maximum allocations.
   (iii) **Finding Opportunity Cost :** Compute the opportunity cost (improvement index) by using the relationship $\Delta_{ij} = c_{ij} - (u_i + v_j)$ for each of the unoccupied (empty) cells.
   (iv) **Test the optimality :** If the opportunity costs of all the unoccupied cells are either positive or zero then the given solution is optimal. But if one or more of the unoccupied cells have negative opportunity cost then the given solution is not optimal and further savings in the transportation cost is possible.
   (v) Select the unoccupied cell with the largest negative opportunity cost.
   (vi) Draw a closed path (or loop) for the unoccupied cell selected in step 5.
   (vii) Determine the maximum number of units that should be shipped to this unoccupied cell.
   (viii) Go to step (ii).

Exercise 4

Q1. A clerk has obtained an initial basic feasible solution to the transportation problem in a following format. Is this solution an optimum solution? If not obtain the optimum solution.

Source ↓	Destination				Capacity
	D_1	D_2	D_3	D_4	
F_1	19 5	30	50	10 2	7
F_2	70	30	40 7	60 2	9
F_3	40	8 8	70	20 10	18
Demand	5	8	7	14	34

Q2. Check the optimality of the given basic feasible solution. If it is not optimal, obtain the optimum solution.

Source ↓	Destination				Capacity
	D_1	D_2	D_3	D_4	
F_1	21 6	16 5	15	3	11
F_2	17	18 5	14 8	13	13
F_3	32	27	18 4	41 15	19
Demand	6	10	12	15	43

Q3. A company has three warehouses W_1, W_2 and W_3. It is required to deliver a product from these warehouses to three customers A, B and C. The warehouses have the following units in stock :

Warehouse :	W_1	W_2	W_3
No. of units :	65	42	43

And customer requirements are

Customer :	A	B	C
No. of units :	70	30	50

The table given below shows the costs of transporting one unit from warehouse to the customer.

Customer ↓	Warehouse		
	W_1	W_2	W_3
A	5	7	8
B	4	4	6
C	6	7	7

Q4. ABC limited has three production shops supplying a product to five warehouses. The cost of production varies from shop to shop and cost of transportation from one shop to a warehouse also varies. Each shop has a specific production capacity and each warehouse has certain amount of requirement. The costs of transportation are given below :

Shops ↓	Warehouse					Supply
	I	II	III	IV	V	
A	6	4	4	7	5	100
B	5	6	7	4	8	125
C	3	4	6	3	4	175
Demand	60	80	85	105	70	400

Find the optimum quantity to be supplied from each shop to different warehouse at minimum total cost.

Q5. The cost of sending a unit from various plants to the warehouses differs as given by the cost matrix below. Determine a transportation schedule so that cost is minimised :

Plants	Warehouses					Supply
	W_1	W_2	W_3	W_4	W_5	
P_1	20	28	32	55	70	50
P_2	48	36	40	44	25	100
P_3	35	55	22	45	48	150
Demand	100	70	50	40	40	300

Q6. Find the initial feasible solution of the following transportation problem by 'Vogel's Approximation Method'. Is the solution optimal?

To→ From↓	W_1	W_2	W_3	Supply
F_1	16	20	12	200
F_2	14	8	18	160
F_3	26	24	16	100
Demand	180	130	150	460

Answers of Exercise 4

1. No, $F_1 \to D_1$ 5 units, $F_1 \to D_4$ 2 units, $F_2 \to D_2$ 2 units, $F_2 \to D_3$ 7 units, $F_3 \to D_2$ 6 units, $F_3 \to D_4$ 12 units, Total Cost Rs. 743,

2. $F_1 \to D_4$ 11 units, $F_2 \to D_1$ 6 units, $F_2 \to D_2$ 3 units, $F_2 \to D_4$ 4 units, $F_3 \to D_2$ 7 units, $F_3 \to D_3$ 12 units, Total Cost Rs. 646,

3. $W_1 \to A$ 65 units, $W_2 \to A$ 5 units, $W_2 \to B$ 30 units, $W_2 \to C$ 7 units, $W_3 \to C$ 43 units, Total Cost Rs. 830,

4. C→I 60 units, A→II 15 units, B→II 15 units, C→II 45 units, A→III 85 units, B→IV 105 units, C→V 70 units, Total Cost Rs. 7605,

5. $P_1 \to W_1$ 40 units, $P_1 \to W_2$ 10 units, $P_2 \to W_2$ 60 units, $P_2 \to W_5$ 40 units, $P_3 \to W_1$ 60 units, $P_3 \to W_3$ 50 units, $P_3 \to W_4$ 40 units, Total Cost Rs. 9240,

6. $F_1 \to W_1$ 50 units, $F_1 \to W_3$ 150 units, $F_2 \to W_1$ 30 units, $F_2 \to W_2$ 130 units, $F_3 \to W_1$ 100 units, Total Cost Rs. 6660

Basic Concepts

1. **Unbalanced Transportation Problem :** So far we have studied that transportation problems in which supply is equal to demand, but in real life it is very rare situation. The transportation problems in which supply is not equal to demand are called unbalanced transportation problems. With some little modifications, the optimal solution of such transportation problems can be obtained by methods discussed earlier. The unbalanced transportation problems may be of following two types :

   (i) *When supply exceeds demand :* This situation is handled by introducing a dummy column whose demand is equal to the difference between supply and demand and then solving the problem as usual.

(ii) *When demand exceeds supply :* This situation is handled by introducing a dummy row whose supply is equal to the difference between demand and supply and then solving the problem as usual.

Exercise 5

Q1. Obtain an initial basic feasible solution to the given transportation problem by North-West Corner Rule :

To→ From↓	W_1	W_2	W_3	W_4	Supply
F_1	21	16	25	13	11
F_2	17	18	14	23	23
F_3	32	27	28	41	19
Demand	6	10	12	15	43

Q2. A company has 3 plants and 3 warehouses. The cost of sending a unit from different plants to the warehouses, production at different plants and demand at different warehouses are shown in the following cost matrix table :

Plants ↓	Warehouse			Production
	A	B	C	
X	8	16	16	152
Y	32	48	32	164
Z	16	32	48	154
Demand	144	204	82	

Determine a transportation schedule, so that the cost is minimised. Assume that the cost in the cost matrix is given in thousand of rupees.

Q3. For the following transportation problem, find the transportation schedule such the cost is minimum.

Plants ↓	Warehouse			Production
	A	B	C	
X	4	8	8	76
Y	16	24	16	82
Z	8	16	24	77
Demand	72	102	41	

Q4. For the following transportation problem, find the transportation schedule such the cost is minimum.

Plants ↓	Warehouse			Production
	A	B	C	
X	4	8	8	56
Y	16	24	16	82
Z	8	16	24	77
Demand	82	102	41	

Q5. Find the optimal solution to the following transportation problem :

To→ From↓	D_1	D_2	D_3	Supply
S_1	6	12	8	500
S_2	8	14	12	300
S_3	20	12	14	450
Demand	350	600	250	1250 / 1200

Q6. A firm has two production centres S_1 amd S_2 with respective production of 200 and 100 units. It has four distribution centres D_1, D_2, D_3 and D_4 with demand of 75 units, 100 units, 100 units and 30 units respectively. The delivery cost per unit of transportation from different production centres to different distribution centres is given below :

Production Centres	**Distribution Centres**			
	D_1	D_2	D_3	D_4
S_1	90	90	100	100
S_2	50	70	130	85

Find the optimum solution so as to minimize the transportation cost.

Answers of Exercise 5

1. Total Cost Rs. 1095,

2. X→B 152 units, Y→B 42 units, Y→C 82 units, Y→Dummy 40 units, Z→A 144 units, Z→B 10 units, Total Cost Rs. 9696,

3. X→B 76 units, Y→B 21 units, Y→C 41 units, Y→Dummy 20 units, Z→A 72 units, Z→B 5 units, Total Cost Rs. 2424,

4. X→B 56 units, Y→A 21 units, Y→C 61 units, Z→A 61 units, Z→B 16 units, dummy→B 30 units, Total Cost Rs. 2504

5. $S_3 \rightarrow D_1$ 350 units, $S_1 \rightarrow D_2$ 150 units, $S_2 \rightarrow D_2$ 300 units, $S_3 \rightarrow D_2$ 150 units, $S_3 \rightarrow D_3$ 250 units, $S_3 \rightarrow$Dummy 50 units, Total Cost Rs. 14,100,]

Basic Concepts

1. **Maximisation Transportation Problems :** To solve the maximization transportation problem, find its dual by deducting all the values from the maximum value, and then solve the problem as usual.

Exercise 6

Q1. A company produces four kinds of dolls A, B, C and D. the monthly supply is 70 units, 40 units, 90 units and 30 units respectively. The dolls are sold through four stores P, Q, R and S. The monthly demands at these stores are 40 units, 50 units, 60 units and 60 units. Profit per unit of dolls sold to each of the stores is given below :

		P	Q	R	S
	A	95	80	70	60
Dolls	B	75	65	60	50
	C	70	45	50	40
	D	60	40	40	30

Suggest optimum policy schedule.

Q2. XYZ Co. has provided the following data seeking your advice on optimal investment strategy :

Investment made at the beginning of the year	Net return data (in paise) of selected Investments				Amount available (lacs)
	P	**Q**	**R**	**S**	
1	95	80	70	60	70
2	75	65	60	50	40
3	70	45	50	40	90
4	60	40	40	30	30
Maximum Investment (lacs)	40	50	60	60	230 / 210

The following additional information's are also provided :

- P, Q, R and S represent the selected investments.
- The company has decided to have four year investment plan.
- The policy of the company is that amount invested in any year will remain so until the end of the fourth year.
- The values (paise) in the table represent net return on investment of one rupee till the end of the planning horizon. (for example, a rupee invested in P at the beginning of year 1 will grow to Rs. 1.95 by the end of the fourth year, yielding a return of 95 paise).

Using the above, determine the optimal investment strategy.

Q3. Following is the profit matrix based on four factories and three sales depots of the company :

Factories	**Sales Depots**			**Availability**
	S_1	**S_2**	**S_3**	
F_1	6	6	1	10
F_2	-2	-2	-4	150
F_3	3	2	2	50
F_4	8	5	3	100
Requirement	80	120	150	

Determine the most profitable distribution schedule and the corresponding profit, assuming no profit in case of surplus production.

Q4. A company has three factories and four customers. The company furnishes the following schedule of profit per unit on transportation of its goods to the customers in rupees :

Factories	Customers				Supply
	A	**B**	**C**	**D**	
P	40	25	22	33	100
Q	44	35	30	30	30
R	38	38	28	30	70
Demand	40	20	60	30	

You are required to solve the transportation problem to maximize the profit and determine the resultant optimal profit.

Answers of Exercise 6

1. A→P 20 dolls, A→Q 50 dolls, B→R 40 dolls, C→P 20 dolls, C→R 20 dolls, C→S 50 dolls, D→S 10 dolls, Total Profit Rs. 13,000

2. 1→P 20 lacs, 1→Q 50 lacs, 2→R 40 lacs, 3→P 20 lacs, 3→R 20 lacs, 3→S 50 lacs, 4→S 10 lacs, Total Profit 13,000 paise

3. Optimal Profit Rs. 480, **4.** Optimal Profit Rs. 5,130